TECHNICAL BULLETIN No. 406 MARCH 1934

A STUDY OF THE RAW COTTON AND THE YARN AND SHEETING MANUFACTURED FROM THREE GRADES OF AMERICAN UPLAND COTTON

BY

The Bureau of Agricultural Economics and
The Bureau of Home Economics
In Cooperation with Clemson
Agricultural College

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

r sale by the Superintendent of Documents, Washington, D.C. - - - - - - - - - - - - - - - Price 10 cents

TECHNICAL BULLETIN No. 406 — MARCH 1934

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

A STUDY OF THE RAW COTTON AND THE YARN AND SHEETING MANUFACTURED FROM THREE GRADES OF AMERICAN UPLAND COTTON

By the *Bureau of Agricultural Economics* and the *Bureau of Home Economics* *in cooperation with Clemson Agricultural College*

CONTENTS

SETTING OF THE PROBLEM

By ROBERT W. WEBB

The principles underlying the program of standardization of cotton quality of the Department of Agriculture are predicated upon the relationships which undoubtedly exist between the properties of cotton fibers and their spinning behavior or efficiency, on the one hand, and between the properties of cotton fibers and the quality of the yarns and fabrics manufactured from them, on the other. Presumably, many different fiber properties are concerned in quality. Practical standards have been promulgated, however, only for length of staple, for grade, and for preparation of long-staple cotton (*45*,[1] *51*, *52*).[2] That the staple and grade standards, so far as they go, have proved themselves to be of much service is evidenced by the fact that they are now

[1] Italic numbers in parentheses refer to Literature Cited, p. 66.
[2] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS. HANDBOOK FOR LICENSED CLASSIFIERS (United States Cotton Standards Act). 30 pp. Washington, D.C. [Mimeographed.]

in common use not only throughout this country but in every other country of the world where American cotton is used in large quantities.

Because of the lack of scientific data upon which to base an accurate system of cotton classification and of the probable time it would require to obtain them, the original basis of the standards and of their graduations necessarily was sought in the experience of the trade, and in the capacities of practical cotton judges to recognize quality variations. Although relations of staple length of raw cotton to the strength and fineness of yarns are generally recognized, they are neither thoroughly understood nor mathematically evaluated.[3] Studies have been made by Willis on the relation of the grade of cotton to its spinning behavior, visible waste, yarn properties, and fabric quality (*55*), but only fragmentary information of an experimental nature is available on the relation of quality of the raw cotton, as indicated by classification, to wearing quality and serviceability of the resulting fabrics.

It was this need of such technical data that prompted, in 1928, the beginning of a cooperative effort between the Bureau of Agricultural Economics and the Bureau of Home Economics to make a more complete study of white cottons selected to represent a relatively wide range of grades. It seemed desirable to know not only the properties of the raw cottons, their behaviors during subjection to the manufacturing processes, and the quality of their yarns and fabrics but also the reactions of the finished products when subjected to service, laundering, and ironing. Sheeting was chosen because of the relative simplicity of its construction and the possibilities of giving it uniform and controlled service.

The initial study reported in this bulletin has embraced American upland White cotton from the Texas area, crop of 1928–29, representing, according to the Universal Standards, a bale of each of the grades of Good Middling, Middling, and Strict Good Ordinary, and, according to the official staple types, approximately 1 inch in staple length. The procedure employed in the manufacture of the sheeting and the observations pertaining to the behavior of the cottons during manufacture and to some properties of the raw cottons and of their intermediate products, yarns, and fabrics are presented in the second part of the bulletin. The studies that deal with the serviceability and the resistance of the fabrics to ironing conditions are reported in the third and fourth parts, respectively.

THE MANUFACTURING PROCEDURE AND SOME PROPERTIES OF THE RAW COTTON, INTERMEDIATE PRODUCTS, YARNS, AND FABRICS[4]

By HORACE H. WILLIS and ROBERT W. WEBB[5]

In the Universal Standards for grades of cotton, three elements of quality, namely, color, leaf and other foreign matter, and prepara-

[3] WEBB, R. W. COTTON QUALITY: WHAT DO WE KNOW ABOUT IT? U.S.Dept.Agr., illus. 1933. [In preparation for a multigraphed publication.]

[4] This study is a part of the program of work of the Division's Cotton Utility and Standards Research Section now under the leadership of R. W. Webb. The yarns and sheetings were manufactured at the Textile School, Clemson Agricultural College, S.C., with textile facilities made available to the Department of Agriculture by the college through cooperative arrangement and under the supervision of H. H. Willis while in charge of the section's spinning activities.

[5] Appreciation is expressed to M. E. Campbell, P. G. Gillespie, W. H. Gray, J. J. Brown, and F. R. Logan, of the spinning laboratory, for assistance rendered and to members in

tion are considered (*45*, *51*, *52* [6]). The possible instability of color, the graduations of the three factor ranges, and the pitch of the different scales give rise to a number of fundamental and practical problems. Some matters of major interest, for example, are the importance of color; the degree to which differences of color in raw cottons reflect themselves through manufactured products in the gray, bleached, and variously dyed states; and the nature and extent to which the grade standards furnish a precise index of the manufacturing utility of a cotton, other things being equal, with respect to staple length and character insofar as the present concepts of these quality factors are concerned. It is recognized, however, that, in addition to the quality of the raw cotton employed, the organization, conditions, and procedure of manufacture, the construction of the manufactured product, and its intended purpose constitute other technical factors which, in various ways and degrees, may influence the quality of resulting cotton goods, the cost of their manufacture, and the evaluation of the quality of the raw cotton.

In an effort to furnish comparable material and data as a background for assistance in determining the importance of those quality elements embraced in or associated with the grade standards, three bales of cotton selected to represent a relatively wide range of grades for so-called "White American upland cotton" have been manufactured under the best controlled and comparable conditions available and have been studied with respect to certain fiber, yarn, and fabric properties. A description of the materials, conditions, and procedure employed in the experimental manufacture of the sheetings and the information obtained from those studies are presented here.

MATERIALS AND METHODS

SELECTION AND EXAMINATION OF THE COTTONS

Since portions of each of the three bales finally selected were to be manufactured into a sheeting, it was desirable to select cottons of such character and staple as to conform as closely as possible to those used in greatest quantity for sheeting. Investigation showed that at the time of this experiment, as a rule, a "hard" cotton about 1 inch in staple length was used. Three bales of approximately the same staple and character but representing three different grades were purchased from a local market at Houston, Tex. Care was exercised that each bale within itself be as nearly uniform as possible in character, leaf, foreign matter, preparation, color, staple length, and regularity of fiber length, as discussed by Palmer (*45*). To this end, each bale was "fanned" at the head (by removing the tie near the top end) and the lint was examined every 3 inches for uniformity of grade, staple, and character.

At the spinning laboratory when the bagging and ties were removed from each cotton a large sample was taken from near the top, middle, and bottom of each of the three bales in an effort to obtain

other laboratories of the section, specifically to Dorothy Nickerson for brilliance determinations, spectrophotometric measurements, and assistance in revising the manuscript; to A. C. Jones for length measurements; to Etta Zeh and H. B. Richardson for yarn, fabric, and moisture tests; and to Carl M. Conrad for suggestions and assistance in revising the manuscript.

[6] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS. See footnote 2.

three samples that would furnish a true and comparable basis for study of the different cottons. These samples were submitted to the Appeal Board of Review Examiners of the United States Department of Agriculture, Washington, D.C., for classification. The Board found the samples to be of Good Middling, Middling, and Strict Good Ordinary grades, respectively, the Middling sample, however, having a slightly rougher preparation than the other two. They called the staple length of the Good Middling and Strict Good Ordinary samples 1 inch, but two times out of three they called the Middling sample 1 1/32 inches, the other time 1 inch. The board found the samples to be regular with respect to staple, medium with respect to body, and normal with respect to strength. These designations represent average characteristics. So far as the board is able to determine, the samples from the three grades did not differ from each other with respect to any of these character elements. The cottons will be identified in subsequent tables not only by their respective grade designations but also numerically by the positions of each in the scale of the nine grades for White cotton beginning with the highest grade.

It is evident from the above descriptions that cottons representing a considerable range in grade were obtained. The finding of the Board that the Middling sample was slightly longer was confirmed by fiber length arrays. As shown subsequently, however, this difference in length, because of its small magnitude, could not have accounted for much of the relatively higher strength of the products from this bale; nevertheless, these slight differences well might be kept in mind when considering the results from the Middling bale.

Color measurements showed that, in comparison with a set of averages of measurements for the nine White grades of the official standards of the United States, the Good Middling bale was bright but not creamy; in fact, its color was close to that of a bright Strict Middling. The Middling bale was creamier than the average and near the upper range of this grade. The color of the Strict Good Ordinary bale was close to the average for this grade.

MANUFACTURING CONDITIONS AND PARTICULARS

In general, the organization and machine speeds and settings were the same for the three cottons and conform to those customarily used by commercial plants for the manufacture of sheetings.

When the ties and bagging had been removed from the bales a quantity of cotton from each was weighed and passed through an opener. These quantities were then placed in separate bins and allowed to condition for at least 24 hours, after which they were reweighed and passed through the following machines:

Picker room	Breaker picker. Finisher picker.
Card room	Card. Drawing frames (two processes). Roving frames (three processes).
Spinning room	Ring spinning frame.

For the manufacture of the sheeting, two counts were spun: 21s with a twist multiplier of 4.50 for the warp yarns and 26s with a twist multiplier of 3.75 for the filling yarns. For comparative purposes, 21s warp yarns also were spun with twist multipliers of 4.25 and 4.75. In addition, 28s warp yarns were spun with the same 3 twist multipliers to provide further information, since cottons of this staple length are usually considered suitable for counts in this range. The organization, speeds, and settings employed for the manufacture of each of the three selected cottons into yarn are shown in tables 1 and 2.

TABLE 1.—*Organization and speeds of machines used in the manufacture of yarns from the 3 selected cottons*

Machine	Organization			Speeds							
	Weight per yard or size	Doubling	Draft	Feed roll		Beater		Fan		Blows per inch	
Pickers:	*Ounces*	*Number*	*Number*	*R.p.m.*		*R.p.m.*		*R.p.m.*		*Number*	
Breaker	13.75			14.0		[1] 977		1,327		7.4	
Finisher	11.00	4	5.00	6.5		[2] 1,377		1,408		45.0	
				Lickerin			Cylinder			Doffer	
	Grains			*R.p.m.*			*R.p.m.*			*R.p.m.*	
Cards	46.0	1	104.62	464			168			10	
				Front roll				Calendar roll			
Drawing frames:				*R.p.m.*				*R.p.m.*			
First	47.5	6	5.81	365				279			
Second	49.0	6	5.82	366				285			
				Front roll		Spindle		Twist setting: Turns per inch		Twist setting: Multiplier	
Roving frames:	*Hanks*			*R.p.m.*		*R.p.m.*		*Number*		*Number*	
Slubber	0.736	1	4.33	181		620		0.92		1.07	
Intermediate	1.95	2	5.30	170		963		1.60		1.15	
Fine	5.50	2	5.64	132		1,360		3.09		1.32	
				Spindle: 3.75 T.m.[4]	Spindle: 4.25 T.m.	Spindle: 4.50 T.m.	Spindle: 4.75 T.m.	Front roll: 3.75 T.m.	Front roll: 4.25 T.m.	Front roll: 4.50 T.m.	Front roll: 4.75 T.m.
Ring spinning frames:											
Warp yarns:	*Counts*			*R.p.m.*	*R.p.m.*	*R.p.m.*	*R.p.m.*	*R.p.m.*	*R.p.m.*	*R.p.m.*	*R.p.m.*
Frame A [3]	21	2	7.64		9,500	9,500	9,500		156	145	138
Frame B [3]	21	2	7.64			8,500				128	
Filling yarns	26	2	9.45	6,200				103			
Do	28	2	10.18		9,250	9,250	9,250		133	122	118

[1] Porcupine beater.
[2] 2-blade beater.
[3] Frame A was used for the spinning test yarns and approximately half the warp yarns. Frame B was used for the remainder of the warp yarns.
[4] T.m.=twist multiplier.

TABLE 2.—*Settings of the machines used in the manufacture of yarns from the 3 selected cottons*

Machine	Settings		
	Feed roll to beater	Grids from beater (top)	Grids from beater (bottom)
	Inches	*Inches*	*Inches*
Breaker picker	3/16	1/2	1/2
Finisher picker	3/16	5/16	11/16
			Gage [1]
Cards	Feed plate to lickerin		10
	Mote knives (top)		15
	Mote knives (bottom)		12
	Lickerin to cylinder		7
	Back plate to cylinder (top)		29
	Back plate to cylinder (bottom)		34
	Flats to cylinder (back)		9
	Flats to cylinder (center)		9
	Flats to cylinder (front)		9
	Front plate to cylinder (top)		29
	Front plate to cylinder (bottom)		34
	Doffer to cylinder		7
	Doffer comb to doffer		22
	Lickerin screen (front)		29
	Lickerin screen (back)		17
	Cylinder screen (back)		29
	Cylinder screen (center)		34
			Inch
	Cylinder screen (front)		3/16
	Drawing rolls [2]		
	First to second roll	Second to third roll	Third to fourth roll
	Inches	*Inches*	*Inches*
First and second drawing frames	1 1/4	1 7/16	1 5/8
Roving frames:			
Slubber	1 7/32	1 3/8	
Intermediate	1 3/16	1 3/8	
Fine	1 5/32	1 5/16	
Spinning frames:			
For Middling cotton:			
Top rolls	1 1/8	1 1/4	
Bottom rolls	1 1/16	1 1/4	
For Good Middling and Strict Good Ordinary cotton:			
Top rolls	1 1/16	1 1/4	
Bottom rolls	1	1 1/4	

[1] Thousandths of an inch.
[2] Measured from center to center of rolls.

The following machines were used to prepare the warp yarns for weaving: Winder, warper, and slasher.

Inasmuch as the available laboratory equipment was not of a size to permit the warping and slashing of the yarns, these processes were carried out by a commercial plant.[7]

The sheetings were woven on an 82-inch plain loom, making 108 picks per minute. The following specifications were followed as closely as possible in making the gray sheetings:

Yarns—21s warp and 26s filling (single yarns).
Construction—64 warp and 64 filling threads per inch.
Width—72 inches.
Weight—1.94 linear yards per pound.

[7] Acknowledgment is made to J. R. Clark, superintendent of Kenneth Cotton Mills, Walhalla, S.C., for services rendered in preparing the warps.

The treatment given the fabrics at the finishing plant[8] was as follows: Kier boiling with 3 percent caustic soda solution at 30 pounds steam pressure; souring with three fourths to 1 percent sulphuric acid solution, chemicking with one fourth of 1 percent available chlorine solution, thorough washing preparatory to finishing, water mangling, starch mangling, drying, dampening, calendering, and manufacturing into sheets.

The ingredients used in the starching operation consisted of a combination of cornstarch and a saponified tallow softening material.

During the manufacture of the three cottons at the spinning and weaving laboratories, the relative humidity was held as nearly constant as possible by means of an automatically controlled humidifying system in each room. The appropriate humidifying heads were turned on 1 or more hours before beginning the daily operation of each machine and they were allowed to operate, as governed by the controls, until the end of the working day or the time when the machines were stopped. The controls were adjusted to maintain 50 percent relative humidity in the picker room, 60 percent in the card room, 70 percent in the spinning room, and 67 percent in the weave room. Although the relative humidity employed in the weave room was slightly lower than that usually adopted by commercial plants, the records show that the number of stoppages for broken warp ends was for the most part very low. In this case, therefore, it was not necessary to maintain a higher relative humidity. During the manufacture of the yarns, hourly readings were made of wet- and dry-bulb temperatures as recorded by psychrometers, located in each room. Similar observations were made in the weave room by means of a sling psychrometer. The averages of the dry-bulb temperatures so obtained, the percentages of relative humidity calculated from the temperature readings, and the time required for processing are shown in table 3. The regain determined for samples of stock taken at the various manufacturing processes is shown in table 4.

TABLE 3.—*Averages of hourly readings of room temperature and of percentage of relative humidity during processing, and number of hours required for each type of machine used in the manufacture of sheeting from the 3 selected cottons*

Machine	Good Middling (No. 3)		Middling (No. 5)		Strict Good Ordinary (No. 8)		Time required for processing
	Temperature	Relative humidity	Temperature	Relative humidity	Temperature	Relative humidity	
	° F.	*Percent*	° F.	*Percent*	° F.	*Percent*	*Hours*
Opener	74	51	81	51	73	50	2
Pickers	76	51	77	51	72	50	6
Card	73	60	74	60	72	60	19
Drawing frame [1]	71	60	73	60	72	60	19
Roving frame [2]	73	60	73	60	74	60	61
Spinning frame [3]	72	70	71	70	72	70	13
Loom	73	66	80	68	80	67	100

[1] Average for 2 processes.
[2] Average for all hanks.
[3] Average for both counts of yarn.

[8] Appreciation is expressed to S. M. Fessenden, general manager, and W. F. Odom, general superintendent, of the Sayles Biltmore Bleacheries, Biltmore, N.C., for cooperation extended in finishing the fabrics and making the sheets in September 1929.

TABLE 4.—*Percentage of moisture regain in samples taken at different processes in the manufacture of sheeting from the 3 selected cottons*

Kind of sample	Moisture regain		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
	Percent	*Percent*	*Percent*
Raw stock (bale)	6.38	8.46	7.64
Raw stock (bin)	6.67	7.82	4.87
Breaker picker lap	6.44	7.35	6.50
Finisher picker lap	6.89	6.78	6.55
Card lap [1]	6.50	6.30	5.63
Card sliver [1]	6.61	6.55	5.35
Drawing sliver [1]	5.88	6.84	5.97
Fine frame roving	6.78	5.99	6.16
Roving in spinning creel [2]	7.56	7.73	7.04
Yarn [2]	7.88	7.99	7.44

[1] Average of 2 samples.
[2] Average of 2 samples reeled and weighed immediately.

METHODS

(1) Moisture regain: Samples weighing 20 grams each were taken at the beginning and at successive stages throughout the manufacture of the yarns. These samples were dried to a constant weight in an oven at 221° to 230° F. according to the methods recommended by the American Society for Testing Materials (*3*). The regain is obtained by expressing the loss in weight as a percentage of the dry weight of the sample.

(2) Fiber length: Samples from the raw material and from the products of successive stages of manufacture were sorted according to length on the Suter-Webb sorter, as described by Webb (*54*), and the length at the 25-percent point in the cumulative weight-length array, reading from the longest fibers, was used as a basis for comparison. The results obtained by two or more sortings were averaged.

(3) Percentage of waste: At each manufacturing process in which the removal of waste is of primary importance, weighings were made of stock fed, stock delivered, and each type of waste removed. From these data the percentages of waste for each of the three lots of cotton were calculated. The small discrepancy usually noted between the weight of stock fed and the sum of the weights of stock delivered and waste recovered is accounted for by invisible loss or gain. Such losses or gains usually contribute so small a percentage of the waste content of cottons that they may be regarded as relatively insignificant.

(4) Strength of yarns (skein): 25 sample bobbins of each twist and number of warp yarn spun were used for strength and size tests.[9] Skeins of 120 yards each were reeled from the bobbins and allowed to condition for at least 3 hours in an atmosphere of 65 percent relative humidity at 70° F. Each skein was then broken on a standard type, motor-driven yarn tester and sized on a

[9] The tests were made in the laboratories of the Division of Cotton Marketing at Washington, D.C.

direct yarn-numbering quadrant.[10] Since it generally is impossible, for a number of reasons, to spin a specified size of yarn, the breaking strengths were adjusted to the specified size according to the usual custom by assuming that, within small limits, they are inversely proportional to the size.

(5) Strength of yarns (single strand): Five bobbins each of 21s and 28s warp yarn spun with a 4.50 twist multiplier from each of the three lots were conditioned for about 4 hours in an atmosphere of 65 percent relative humidity at a temperature of 70° to 73° F. Approximately one hundred and fifty 12-inch lengths of yarn from each bobbin were broken successively on a Moscrop automatic single-strand yarn tester.

On this machine a 12-inch strand of yarn is grasped at one end by a movable jaw, the other end being attached to a calibrated spiral spring. Tension is applied to the yarn and to the spiral spring

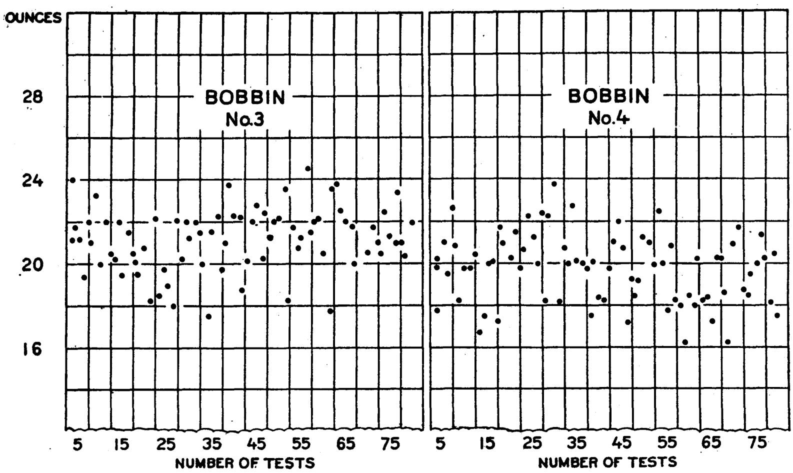

FIGURE 1.—Section of Moscrop chart showing strength of single-strand 21s yarn, 4.75 twist multiplier, spun from the selected cotton of Middling (No. 5) grade.

until the yarn breaks. When this occurs, the maximum elongation of the spring is recorded on a chart by means of a needle point which pierces the chart, the results being read directly in ounces. Figure 1 shows a section of the type of chart used in connection with this machine.

In this test the data recorded on the perforated chart were later assembled in tabular form, and the average strength of yarn of each lot was calculated. The averages thus calculated were corrected for the exact yarn number (21s or 28s) by assuming that, within their ranges, the strength of the yarn is inversely proportional to the count. In making the corrections the average sizes of the 25 skeins of 21s and 28s yarn, respectively, spun with a 4.50 twist multiplier, were used.

---

[10] When the balance does not indicate the size directly, the yarn size or number may be calculated from the formula:

$$\text{Yarn size or number} = \frac{\text{Length in yards of single yarn}}{\text{Weight in grains}} \times \frac{7{,}000 \text{ (grains in 1 pound)}}{840 \text{ (yards per hank of cotton yarn)}}$$

(6) Brilliance: Measurements of brilliance were made on the raw material and on products of successive stages of manufacture by means of a Keuffel & Esser disk colorimeter. The instrument and the method have been described by Nickerson, (*41*, *42*, *43*). Briefly, it consists in so adjusting the area of a set of four color disks that the light coming from them is equal in hue, brilliance, and chroma to that coming from the sample. The colors from the disks are mixed by a rotating prism, and adjustment is facilitated by comparing the light from the two sources on adjacent half-circular fields. The expression of brilliance is made in equidistant units from black to white, as illustrated in the Munsell Book of Color (*38*).

(7) Spectrophotometric measurement: Spectrophotometric measurements were made on a Keuffel & Esser color analyzer, the reflections at different wave lengths being expressed as a fraction of those from a magnesium carbonate block, as described by Keuffel (*31*).

(8) Tensile strength of fabrics: Fifteen samples of fabric were cut warpwise and 15 fillingswise from both the gray and the finished fabric woven for each of the three cottons. Three samples, each approximately 7 by 1¼ inches in size, were conditioned overnight in an atmosphere of 65 percent relative humidity at a constant temperature of 70° F. The "strip" method (*3*) of testing the fabric was used, each specimen being raveled to a width of 1 inch before being tested. The fabrics were broken on a regular power-driven tester of the inclination balance type, with the jaws of the machine set 3 inches apart and the bottom or pulling jaw moving at a rate of 12 inches per minute. For purposes of correction, the actual constructions of the cloths were determined by counting the warp and filling threads per inch of fabric, observations being made in six places on large samples of both the gray and the bleached fabrics.

(9) Bursting strength of fabrics: Three specimens of each fabric were exposed for at least 3 hours in an atmosphere of 65 percent relative humidity at about 73° F. Each specimen was then tested in five places on a hand-operated Mullen bursting-strength tester. From the data for bursting strength per square inch thus obtained an average was calculated.

RESULTS OF TESTS

PERCENTAGE OF WASTE REMOVED AT CERTAIN PROCESSES

The percentages of each type of waste removed from each of the cottons by the pickers and card, based on net weight of cotton fed to these particular machines, are listed in table 5. Figure 2 shows graphically the percentages of the fractionated and total wastes based on the weight of cotton fed to the opener breaker.

Examining the results for total visible waste for the three 1-inch cottons, it is observed that a waste of 6.40 percent was obtained for the Good Middling grade; 6.06 percent for the Middling; and 12.99 percent for the Strict Good Ordinary. The percentages for Good Middling and Strict Good Ordinary are well within the range of those usually obtained for such grades under similar picking and carding conditions. That for the Middling cotton, however, may be considered somewhat low for this grade. These comparisons are made on a basis of a large amount of data compiled at the spinning laboratory and of observations elsewhere.

TABLE 5.—*Percentages of the different types of waste removed by the pickers and the card in the manufacture of the 3 selected cottons*

Kind of waste	Waste percentage [1]		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
Picker waste:			
Breaker:	*Percent*	*Percent*	*Percent*
Visible	0.57	0.43	1.94
Invisible	[2] .09	.33	.53
Finisher:			
Visible	.85	.68	2.54
Invisible	.13	.06	.24
Card waste:			
Flat strips	2.36	2.67	3.20
Cylinder and doffer strips	.49	.61	.76
Motes and fly	2.07	1.73	5.03
Sweepings	.13	.03	.05
Total visible	5.05	5.04	9.04
Total invisible	.31	.42	.51
Picker and card waste:			
Total visible	6.40	6.06	12.99
Total invisible	.35	.80	1.24

[1] The waste percentage for each cleaning machine is based on the net weight of cotton fed to that particular cleaning machine. The percentage of total visible waste removed by the pickers and card equals 100 times the sum of the pounds of waste removed by the pickers and card divided by the net weight fed to the opener picker. Invisible waste is figured similarly.
[2] Invisible gain.

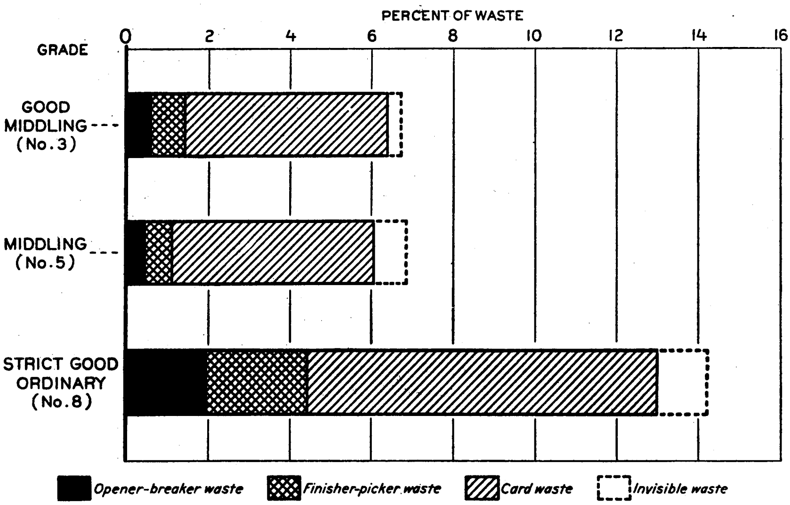

FIGURE 2.—Percentages of picker and card waste from the three selected cottons. (Based on net weight fed to opener.)

CHANGES IN FIBER LENGTH DURING MANUFACTURE INTO YARN

The lengths of fiber at the 25 percent point in the cumulative weight-length arrays for samples of the raw cotton and for those taken at certain stages of processing from each of the three cottons tested are shown in table 6.

TABLE 6.—*Length of fiber in the raw stock and products from certain successive stages in the manufacture of 21s warp yarn from the 3 selected cottons*

Kind of sample	Length of fiber [1]		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
	Inches	*Inches*	*Inches*
Raw stock	1.001	1.022	0.986
Breaker picker lap	1.003	1.025	.991
Finisher picker lap	.998	1.077	1.007
Fine frame roving	1.015	1.069	1.017
Yarn	.993	1.010	.964

[1] Length calculated at the 25 percent point in the cumulative weight array, reading from the longest fibers.

The standard error of the difference between any two reported lengths is about plus or minus 0.018 inch. With this figure in mind, it is seen that the fiber length of the different products from the Good Middling cotton did not change significantly during the course of manufacture, nor did the Strict Good Ordinary cotton change significantly prior to the spinning process. The Middling cotton fiber length appears to have increased at the finisher picker lap and to have decreased again during the spinning process. But the small quantity of waste removed is not sufficient to explain this apparent increase in length at the finisher picker. Besides, no corresponding increase in the fiber lengths of the other two grades was noted at this point. It is concluded, therefore, that the greater fiber lengths for the finisher picker lap and fine frame roving in the case of Middling cotton resulted from slight errors, either in the measurements on the products or in failure to obtain representative samples. It is of interest, however, that the relationships of fiber lengths in the yarns are in general agreement with those in the raw cottons.

END BREAKAGE DURING SPINNING

The number of ends breaking per hundred spindles per hour for the 21s yarns of 4.50 twist multiplier are shown in table 7.

TABLE 7.—*End breakage per hundred spindles per hour during spinning of the 3 selected cottons*

Count of yarn	End breakage [1]		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
	Ends	*Ends*	*Ends*
21s	0.65	0.84	1.41

[1] Approximately 2,100 to 2,400 spindle hours involved in each case.

The results for the three selected cottons are seen to increase directly as the grade becomes lower.

STRENGTH AND IRREGULARITY OF WARP YARNS (SKEIN)

The breaking strengths of skeins prepared from 21s and 28s warp yarns for each twist multiplier for each of the 3 grades are shown in table 8. The skein strengths are plotted in figure 3.

TABLE 8.—*Average strength of yarn per skein for the 3 selected cottons*

Count of yarn	Twist multiplier	Strength of yarns		
		Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
		Pounds	*Pounds*	*Pounds*
21s	4.25	115.0	115.7	97.0
	4.50	114.5	114.4	98.2
	4.75	113.8	112.2	96.7
Average		114.4	114.1	97.3
28s	4.25	78.0	79.2	64.7
	4.50	79.5	78.3	65.9
	4.75	78.6	79.0	64.5
Average		78.7	78.8	65.0

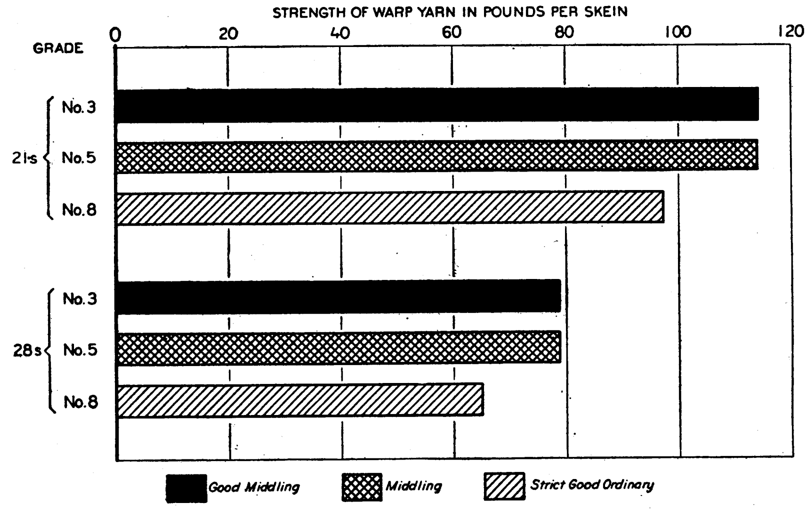

FIGURE 3.—Average strengths of yarn determined by the skein method for three twists of 21s and of 28s warp yarns manufactured from the three selected cottons.

By reference to table 8 and figure 3 it can be seen that the skein strengths of yarns spun from the Good Middling and Middling cottons are approximately equal and much higher than those from the Strict Good Ordinary cotton. The close agreement of the strength of the yarn from Middling to that of the yarns from Good Middling probably may be considered by some to be due to the slightly greater staple length of the Middling bale. However, on a basis of several hundred bales of American upland cotton, ranging from $\frac{13}{16}$ to $1\frac{1}{4}$ inches, spun in the laboratory at Clemson College, $\frac{1}{32}$-inch increase in staple length has given on the average for 22s yarn an increase of only 2.07 pounds, or 2.15 percent, when based upon the average strength of 22s yarn spun from 1-inch staple. It is obvious, therefore, that other reasons account for the close agreement. The two higher grades produced yarns of excellent strength for cotton of their length, whereas those from the lowest grade are considered fair. These comparisons also are made on a basis of results compiled at the spinning laboratory.

The irregularity of yarn as indicated by the highest, lowest, and average skein-breaking strength and size, and the average deviation and extreme variation of both breaking strength and size, for 21s warp yarns spun with 4.50 twist multiplier, are shown in table 9.

TABLE 9.—*Highest, lowest, and average breaking strengths and sizes and percentage of average deviation and extreme variation of break and size of 21s warp yarns of 4.50 twist multiplier spun from the 3 selected cottons*

Grade	Breaking strength			Yarn size			Average deviation [1]		Extreme variation [2]	
	Highest	Lowest	Average [3]	Highest	Lowest	Average [3]	Breaking strength	Size of yarn	Breaking strength	Size of yarn
	Pounds	*Pounds*	*Pounds*	*Count*	*Count*	*Count*	*Percent*	*Percent*	*Percent*	*Percent*
Good Middling (No. 3)	124	106	114.5	22.00	20.25	20.99	3.44	1.96	15.72	8.34
Middling (No. 5)	129	109	114.4	21.25	19.50	20.41	3.83	1.96	16.99	8.57
Strict Good Ordinary (No. 8)	106	92	98.2	21.75	20.25	20.79	3.44	1.67	14.11	7.22

[1] Calculated by summating all deviations from the mean without regard to sign, then averaging and expressing as a percentage of the mean.
[2] Expressed as a percentage of the mean.
[3] Average of 25 observations.

The differences in irregularity are seen to be small, any advantage of regularity being associated with the yarns from the Strict Good Ordinary bale.

STRENGTH AND IRREGULARITY OF WARP YARN (SINGLE STRAND)

The corrected average single-strand breaking strengths and percentage of average deviation from 21s and 28s warp yarns of 4.50 twist multiplier are shown in table 10 and presented graphically in figure 4. Frequency curves of the breaking strengths of the 21s yarns are shown in figure 5 and of the 28s yarns in figure 6. These curves show the relative dispersion and skewness for each of the three grades.

The results of the single-strand strength tests, insofar as the relative order of yarn strength of the three cottons is concerned, confirm those of the skein tests. The cottons of the Good Middling and Middling grades gave very nearly equal strengths, whereas the cotton of the lowest grade, Strict Good Ordinary, gave yarns of considerably lower strength. In the case of the 21s yarns, the strength decreased in the order of grade; but for the 28s yarns the intermediate grade furnished the greatest strength, and the lowest grade exhibited the least strength. It is well to point out that, as sized in the skein, the 28s yarn from the Middling cotton was about 2.5 percent heavier than that from either of the other two grades. Since no correction to specified size was employed in the single yarns, this probably accounts in part for the change in the order of strengths.

TABLE 10.—*Average strength of single-strand 21s and 28s warp yarn of 4.50 twist multipliers, and percentage of average deviation of yarn strength for the 3 selected cottons*

Grade	Strength of warp yarns [1]		Average deviation [2]	
	21s	28s	21s	28s
	Ounces	*Ounces*	*Percent*	*Percent*
Good Middling (No. 3)	16.7	10.5	8.4	9.9
Middling (No. 5)	16.2	11.2	8.3	10.0
Strict Good Ordinary (No. 8)	13.7	9.5	7.6	10.5

[1] Average based on approximately 775 individual breaks made by Moscrop tester. Average counts of 25 skein observations made on the respective yarns were used as a basis in correcting the data.
[2] Calculated by summating all deviations from the mean without regard to sign, averaging, and expressing as a percentage of the mean.

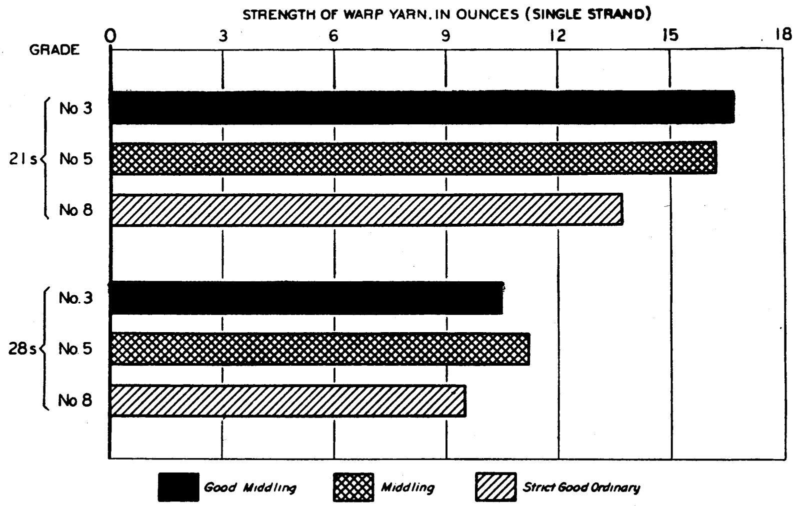

FIGURE 4.—Average strengths of yarn determined by the single-strand Moscrop tester for 28s warp yarns, 4.50 twist multiplier, manufactured from the three selected cottons.

Relatively, the results of the single-strand strength tests for 21s yarns show a slightly greater difference between Good Middling and Middling than do the skein strength tests for these grades (figs. 2 and 4). It may be calculated from the results of both methods of testing upon both counts of yarn that the strength of yarns spun from the Strict Good Ordinary cotton ranges from 10 to 18 percent below that of yarns spun from the cotton of Good Middling grade.

Data having been presented concerning both the skein and the single-strand strength of the yarns, it is of interest to ascertain the relation existing between these two sets of values. A skein of yarn, as placed on the usual type of strength tester, contains the equivalent of 160 single strands of yarn each 27 inches in length. Theoretically, if all the individual strengths were realized in breaking a skein, the ratio of skein strength to single strand strength would be 160 : 1.

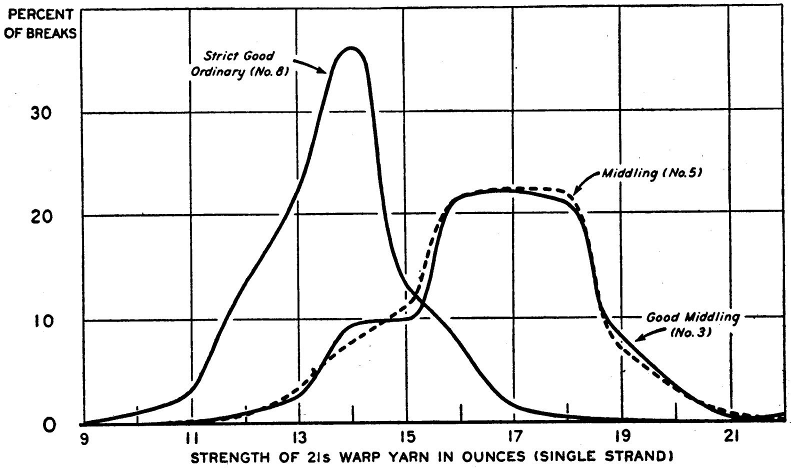

FIGURE 5.—Distribution of strengths of single-strand 21s warp yarn, 4.50 twist multiplier, manufactured from the three selected cottons. Each curve represents approximately 775 observations as recorded by the Moscrop tester. Curves were drawn from original data which were not corrected for size of yarn.

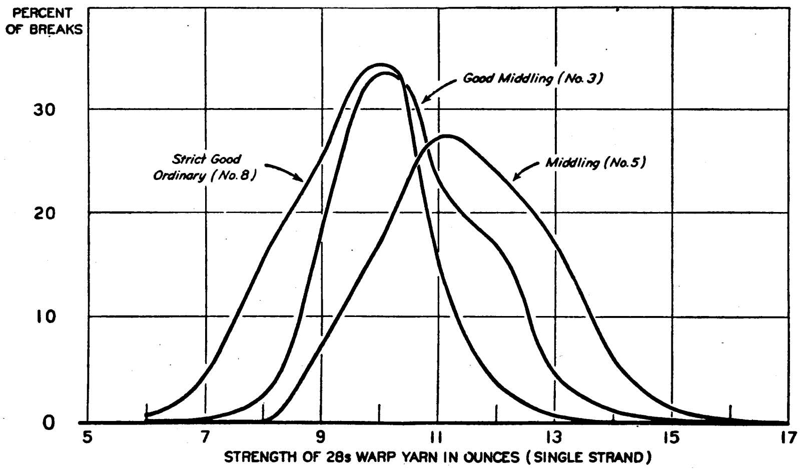

FIGURE 6.—Distribution of strengths of single-strand 28s warp yarn, 4.50 twist multiplier, manufactured from three selected cottons. Each curve represents approximately 775 observations as recorded by the Moscrop tester. Curves were drawn from original data which were not corrected for size of yarn.

This ratio is not actually realized, however, since there is a tendency for the weaker strands to break first, followed by slipping of many of the stronger threads. The ratio of skein strength to single-strand strength for each of the yarns under consideration under the conditions of this test is as shown in table 11.

TABLE 11.—*Ratio of skein strength to single-strand strength*

Grade	Size of yarn	
	21s	28s
Good Middling (No. 3)	109.6:1	121.4:1
Middling (No. 5)	112.9:1	111.8:1
Strict Good Ordinary (No. 8)	115.1:1	110.8:1
Theoretical	160.0:1	160.0:1

The results of this test indicate that in the case of 21s yarn a greater proportion of the single-strand strength was realized in the skeins as the grade became lower, whereas for the 28s yarn the reverse was the case.

As in the case of the skein strengths, the 21s yarn from the lowest grade was most regular; but in the case of 28s, this grade gave the most irregular yarn, followed in order by the intermediate and the highest grade.

COLOR MEASUREMENTS OF RAW STOCK, INTERMEDIATE PRODUCTS, AND FABRICS

Color measurements were made on samples of the cotton from the raw stock, the breaker and finisher laps, and the finished gray and bleached material. The relation of brilliance to grade, as the raw stock passed through the breaker and finisher and then into the gray and bleached cloth, is shown in table 12 and graphically in figure 7.

TABLE 12.—*Brilliance of raw stock, certain intermediate products, and fabrics manufactured from the 3 selected cottons*

Kind of sample	Brilliance [1]		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
Raw stock	8.96	8.60	7.80
Breaker-picker lap	8.92	8.40	7.71
Finisher-picker lap	9.04	8.68	7.84
Gray cloth	8.57	8.23	7.57
Bleached cloth	9.80	9.70	9.40

[1] Scale of brilliance extends from 0 (black) to 10 (white).

An examination of the results shows that the brilliance of the raw stock and of products varies with the grade; that is, the higher the grade the greater the brilliance. Generally, the Middling cotton is nearer in brilliance to the Good Middling cotton than to the Strict Good Ordinary. The breaker-lap samples measured a trifle darker than the raw stock, perhaps owing to the fact that the cotton was opened up and the trash loosened. Samples from the finisher-picker lap showed up brighter than those from either the breaker-picker lap or the raw stock, indicating that some of the trash had been removed.

The brilliance measurements reported for the gray and bleached cloths are the result of determinations made on a sample of several layers stretched over a white background, sufficient layers being taken to overcome any effect of the background. It is seen that these figures are in all cases lower than those of the finisher-picker lap. This is owing, no doubt, to the fact that the cotton, although itself a trifle brighter, in the form of cloth caused more shadows than occurred in the finisher-picker lap. The measurements of the gray cloth indicate a difference in brilliance between the Good Middling and Strict Good Ordinary cottons which is comparable to the difference in the raw stock. After bleaching, the brilliance is raised considerably, the low grades being raised relatively more than the high.

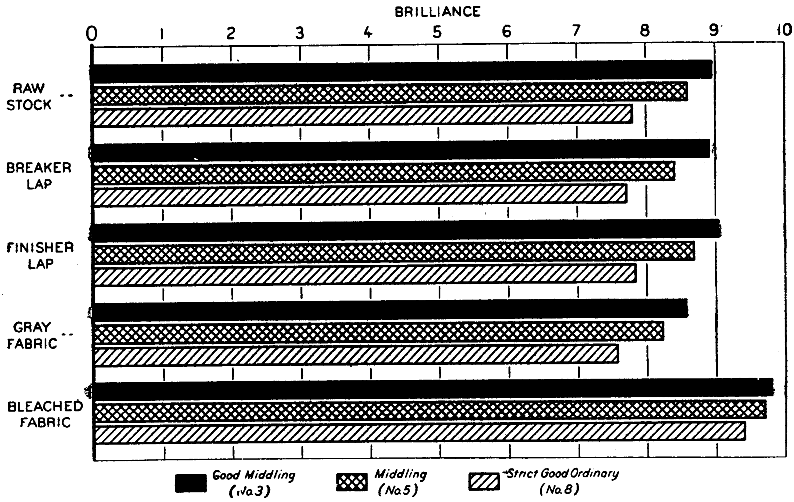

FIGURE 7.—Brilliance of the raw stock of certain intermediate products, of the gray, and of the bleached fabrics manufactured from the three selected cottons.

Spectrophotometric measurements [11] of the reflections at each of seven different wave lengths from the gray and from the bleached cloth are shown in table 13 and presented graphically in figure 8.

These measurements of reflection by wave length, when plotted on a logarithmic scale, show results very similar to those obtained from the brilliance measurements. Brilliance is measured in units equal to the eye and bears a definite relation to percentage of light reflected. It has been thought by some to bear a logarithmic relationship and, although this does not agree precisely with the Munsell scale, it is used in figure 8 in order to show the general relationship. The two sets of figures cannot be precisely adjusted, since the illumination under which they were measured and the thickness of the material differed for the two measurements. The grades maintain approximately relative positions with respect to relative reflection of the wave lengths measured. The reflections of the gray cloths, which are a light dull yellow in color, were less from the blue end of the spectrum than from the red end. The

[11] These measurements were made on a Keuffel & Esser color analyzer through the courtesy of Carl W. Keuffel.

bleached cloths gave a much higher relative reflection throughout the range of wave lengths, and the reflections did not differ appreciably for the different wave lengths. This is a fact which corresponds to their whiteness, since the higher and flatter the curve, the whiter the color.

TABLE 13.—*Reflection at different wave lengths of gray and of bleached cloth manufactured from the 3 selected cottons*

Wave length in mμ	Reflection [1]					
	Gray			Bleached		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
440	0.52	0.52	0.43	0.84	0.80	0.76
480	.55	.54	.43	.87	.83	.82
520	.60	.57	.47	.89	.86	.83
560	.65	.60	.49	.89	.85	.83
600	.67	.63	.52	.89	.84	.84
640	.70	.66	.53	.90	.86	.85
680	.74	.67	.56	.91	.87	.86

[1] Results expressed relative to the reflection of magnesium carbonate.

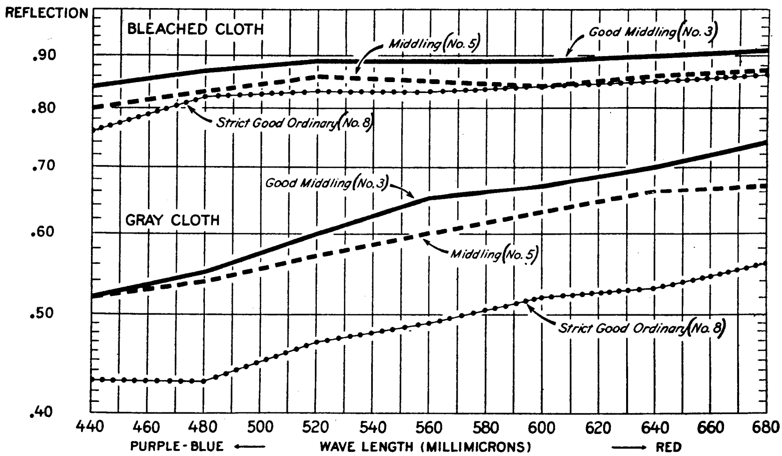

FIGURE 8.—Relative spectral reflectance of gray and bleached fabrics manufactured from the three selected cottons.

FOREIGN MATTER IN THE FABRICS

The gray fabrics from the different grades differed noticeably in their appearance to the eye in color, luster, and amount of foreign matter present on the surface. The gray fabric prepared from the Good Middling cotton was a bright, creamy white, with a very small quantity of fine pin trash. That prepared from the Middling cotton had a slightly darker, grayish-yellow cast, much duller than that made from the Good Middling cotton, and the trash was a little more noticeable. The gray fabric prepared from the Strict Good Ordinary cotton had a still darker, grayish-yellow color and considerably more pin trash than that from the Middling cotton.

That a quantitative relationship between grade and surface foreign matter might be established for the gray fabrics, the average number of particles of trash in a surface area of 9 square inches was determined. This was done by placing a mat with a 3-inch square opening on the smooth surface of the cloth and counting the particles in each of 20 such areas. The average number of particles of foreign matter observed per 3-inch square on the gray from each of the three grades was as follows:

	Average number of particles per 3 by 3-inch square
Good Middling (No. 3)	7.2
Middling (No. 5)	10.7
Strict Good Ordinary (No. 8)	23.9

The bleached samples from each of the three grades differed little as to pin trash, practically all of this material having been removed in the finishing process. When the finished fabrics were placed side by side, however, a difference in color and luster between the Good Middling and Strict Good Ordinary cotton was easily discernible. Differences between the fabrics from the Middling cotton and those from either of the other grades were much less noticeable.

TENSILE STRENGTH OF THE FABRICS

The averages for the number of threads per inch both warpwise and fillingwise for the gray and bleached fabrics are shown in table 14, and the corresponding strengths are shown in table 15.

TABLE 14.—*Construction of gray and bleached fabrics manufactured from the 3 selected cottons*

Grade	Threads per inch [1]			
	Gray		Bleached	
	Warpwise	Fillingwise	Warpwise	Fillingwise
	Number	*Number*	*Number*	*Number*
Good Middling (No. 3)	65	64	72	62
Middling (No. 5)	65	63	72	63
Strict Good Ordinary (No. 8)	65	65	71	60

[1] Each average represents 6 observations.

TABLE 15.—*Tensile strength of gray and bleached fabrics from the 3 selected cottons*

Grade	Tensile strength of 1-inch strip [1]			
	Gray		Bleached	
	Warpwise	Fillingwise	Warpwise	Fillingwise
	Pounds	*Pounds*	*Pounds*	*Pounds*
Good Middling (No. 3)	63.0	50.3	63.8	41.4
Middling (No. 5)	60.6	49.0	65.2	38.8
Strict Good Ordinary (No. 8)	52.1	43.8	51.5	31.1

[1] Each average represents 15 observations.

It may be seen from table 14 that the number of warp threads per inch of the finished sheetings was considerably higher than that of the gray whereas the number of filling threads per inch was more nearly the same. This change in construction is explained by the fact that, in the finishing process, the fabrics shrank on an average of 10 inches in width, from 72 to 62 inches, the length changing but slightly, approximately 3 percent.

Table 16 and figure 9 show the figures of table 15 converted to a comparable basis, namely, a construction of 64 by 64 threads per inch. The corrected tensile strength of the fabrics in all cases, except that of the bleached fabric tested warpwise, decreased with the grade. In the case of the exception noted, the fabric from the Good Middling had a somewhat lower strength than that from the Middling cotton but a considerably higher strength than that from the Strict Good Ordinary cotton. In all cases the fabrics from Middling showed a strength much closer to that of fabrics from Good Middling than to that of fabrics from Strict Good Ordinary.

TABLE 16.—*Corrected tensile strength of gray and bleached fabrics manufactured from the 3 selected cottons*

Grade	Tensile strength corrected for 64 by 64 construction [1]			
	Gray		Bleached	
	Warpwise	Filling-wise	Warpwise	Filling-wise
	Pounds	*Pounds*	*Pounds*	*Pounds*
Good Middling (No. 3)	62.0	50.3	56.7	42.7
Middling (No. 5)	59.7	49.8	58.0	39.4
Strict Good Ordinary (No. 8)	51.3	43.1	46.4	33.2

[1] Based on data shown in tables 14 and 15, no allowance being made for the fabric assistance.

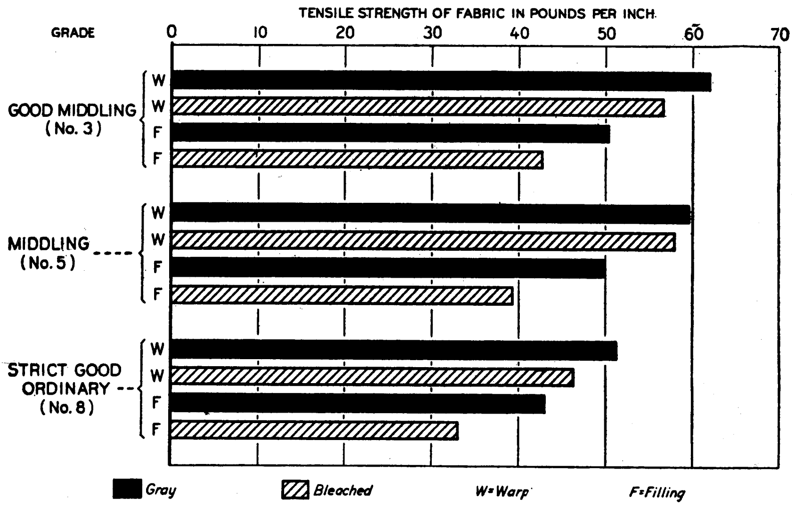

FIGURE 9.—Average corrected tensile strength determined by the strip method for the gray and for the bleached fabrics manufactured from the three selected cottons. (Each bar represents the average of 15 observations.)

On an average the corrected strength of the bleached fabric, as determined by the strip method, decreases 6.9 percent warpwise and 19.5 percent fillingwise.

BURSTING STRENGTH OF THE FABRICS

The average bursting strength per square inch for the gray and bleached fabrics from each of the three grades is shown in table 17 and figure 10.

TABLE 17.—*Average bursting strength of gray and bleached fabrics manufactured from the 3 selected cottons*

Grade	Bursting strength per square inch per fabric [1]	
	Gray	Bleached
	Pounds	*Pounds*
Good Middling (No. 3)	153.7	106.0
Middling (No. 5)	154.7	104.3
Strict Good Ordinary (No. 8)	126.7	79.0

[1] Each average represents 15 tests made on a Mullen tester.

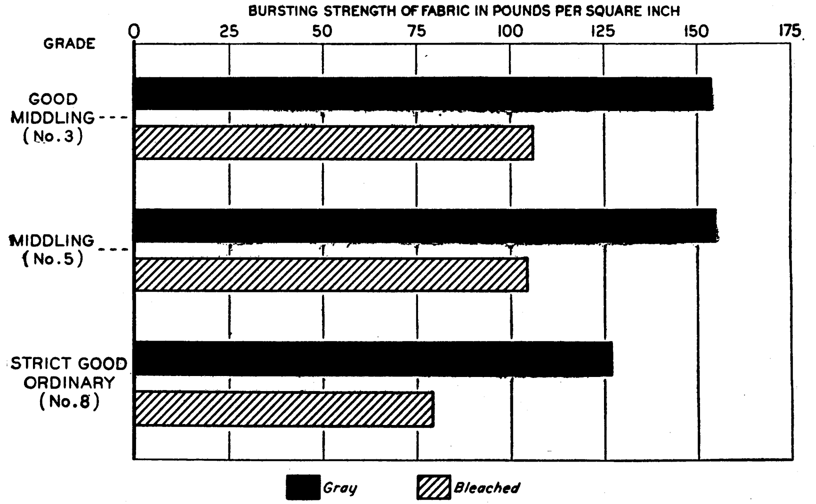

FIGURE 10.—Average bursting strength determined by a Mullen tester for the gray and for the bleached fabrics manufactured from the three selected cottons. (Each bar represents average of 15 observations.)

The results show very little difference in strength between the fabrics, either gray or bleached, manufactured from the Good Middling and Middling cottons. The fabrics manufactured from the two higher grades were much stronger than those manufactured from the Strict Good Ordinary cotton. The finishing process apparently lowered the bursting strength of the fabrics about one third. For the gray fabric, it was observed that in the majority of cases the filling threads broke as the fabric burst, whereas in the finished fabrics the warp threads broke in every instance.

CONCLUSIONS

The more important results obtained in the manufacture of the three selected cottons into sheeting and from certain studies made on their fibers, intermediate products, yarns, and fabrics under the conditions, as described, are listed as follows:

As compared with previous results obtained from cottons of the same grades and similar staple, the percentage of waste removed from the Good Middling and Strict Good Ordinary cottons was about average. On the other hand, the waste from the Middling cotton was somewhat lower than would be expected for this grade.

The length of fibers differed slightly for the three bales, that for the Middling bale being a trifle longer than that for the other two. On a basis of previous results, however, the small differences in length of raw cotton would not be expected to account for the relatively higher strength of the products from this bale.

The length of fibers from the three bales of cotton did not change appreciably in the course of the manufacturing processes.

The number of ends breaking per 100 spindles per hour increased as the grade became lower and was more than double for the Strict Good Ordinary than for the Good Middling cotton.

Both skein and single-strand tests on 21s and 28s warp yarns showed the Good Middling and Middling cottons to have approximately equal strength. The Strict Good Ordinary cotton gave yarns from 10 to 18 percent weaker by both skein and single-strand tests than either of the other grades of this test.

In both the skein and the single-strand strength tests on 21s warp yarn, the Strict Good Ordinary cotton showed slightly more regularity than for either of the other two grades. This regularity was correlated with regularity of size in the skein tests. In the single-strand tests of 28s warp yarn, the regularity decreased with the grade.

The brilliance of the cottons decreased as the grade became lower. The cottons of the three grades retained their relative positions with respect to brilliance throughout the manufacturing processes, but the spread became smaller after bleaching.

Spectrophotometric measurements of the reflection of light from the gray and bleached fabrics for each of the three grades agreed, in general, with the brilliance measurements. The gray cloth, because of its yellow color, gave a greater reflection toward the red end of the spectrum, while the bleached cloth, on the other hand, gave more nearly the same relative reflection throughout the range of wave lengths used.

The average number of fine particles of foreign matter in the gray cloth increased greatly as the grade became lower, but they largely disappeared after the finishing process.

A reduction in the width of the gray fabric from 72 inches to about 62 inches occurred as a result of the finishing process, whereas the length increased approximately 3 percent.

The corrected tensile strength of strips of gray and of bleached fabrics decreased as the grade became lower except in one case in which the bleached fabric from the Middling cotton tested warpwise was stronger than the corresponding fabric from the Good Middling. Relatively, the tensile strength of the fabric from the Middling cotton was much nearer that from the Good Middling than that of the

Strict Good Ordinary cotton. On an average the corrected strength of the bleached fabric as determined by the strip method decreases 6.9 percent warpwise and 19.5 percent fillingwise over that of the gray fabric.

The bursting strength of the gray and of the bleached fabrics from the Good Middling and Middling cotton was about equal and was much higher than that of the gray and of the bleached fabric made from the Strict Good Ordinary cotton. Bleaching resulted in a reduction of approximately 33 percent in bursting strength per square inch for the fabrics manufactured from each of the three grades.

Discrepancies between observation and expectation, noted in a few instances particularly in the case of the Middling bale, are not surprising when it is considered that many of the important fiber properties which are involved in cotton quality are beyond the province of the grade factors and the grade designations. These fiber properties, moreover, may vary greatly for a given grade and it must be evident that only insofar as they collectively assume mean values for a given bale can that bale be said to represent the particular grade category.

SERVICEABILITY OF THE FABRICS

By MARGARET B. HAYS and RUTH E. ELMQUIST

In connection with investigations of various aspects of cotton utilization, the Department is attempting to evaluate different grades and varieties of cotton in terms of their relative usefulness in finished fabrics. In this study, sheetings made from American upland cotton, selected to represent the Good Middling, Middling, and Strict Good Ordinary grades, were submitted to laboratory and wearing tests. For details of the construction and manufacture of these fabrics see page 6.

No investigations of the durability of known grades of cotton when woven into fabrics are reported in the literature although a few studies have been made of the reaction to laundering of fabrics made of cotton of unknown grade and staple. The effect of repeated washing on some damasks, sheetings, and shirtings was published by Griffith and her coworkers (*26*) and the durability of ginghams and five white cotton fabrics when subjected to laundering was reported by Ginter and Rhodes (*24*). Furry and Edgar (*21*, *22*) analyzed 109 commercial brands of sheeting and the deterioration of 5 of these due to laundering was studied by Griffith and Edgar (*25*). MacDonald (*36*) reported an investigation by Consumers' Research, Inc., in cooperation with the New England Laundries, on the loss due to washing and to washing plus ironing of 10 brands of sheets having the largest volume of sales in 3 Boston stores. A preliminary report (*5*) has been published by the Cotton Textile Institute of a study begun in 1928, in which 24 mill brands of sheeting were subjected to actual service in the Grasslands Hospital in Westchester County, N.Y. Carpenter[12] and Miller[13] have compared the deterioration of sheets washed at a

[12] CARPENTER, C. E. COMPARATIVE ANALYSIS OF NINE BRANDS OF SHEETS. 1928. [Unpublished master's thesis. Copy on file Dept. Home Economics, Univ. Chicago, Chicago.]

[13] MILLER, E. M. AN ANALYTICAL STUDY OF COMMERCIAL BRANDS OF SHEETS. 1929. [Unpublished master's thesis. Copy on file Dept. Home Economics, Univ. Chicago, Chicago.]

commercial laundry and in the laboratory. The effect of commercial laundering on 24 brands of sheets was also investigated by Millard (*1*) in a study in which they were washed 160 times without wear.

The grade and staple of the raw cotton used in the fabrics was not taken into consideration by these investigators and they did not follow the chemical changes produced by laundering. In the present study, changes in the chemical, as well as the physical characteristics of the sheetings were investigated.

WEARING TEST

No laboratory test has yet been devised which approximates actual service conditions. Therefore, in order to study the reaction of these grades of cotton to wear, the finished sheets were put into service in a Washington hotel.[14] This hotel maintains its own laundry and the staff cooperated to control the conditions both of the use and the laundering of the sheets. Variables in laundering procedure due to changes in personnel during the 2½ years the test was in progress, were not significant.

Thirty sheets of each of the three grades of cotton were marked with an individual identifying number. Before being used, they were given 2 hot rinses and 1 cold rinse to remove the finishing material. After the excess of water was removed by extraction, they were ironed, dried thoroughly, and put into service on a transient-guest floor of the hotel. The beds had no rough edges on the frames or springs which would cause undue wear.

Two sheets were used per bed each day, the wide hem always being placed at the head of the bed. It is assumed that over a long period each was used an equal number of times as the top and as the bottom sheet, and that the wear was uniform at any testing period. All sheets, except those removed for testing, were used as long as serviceable. According to the hotel routine, those laundered one day were not put on the beds until the next day, but were stored overnight to permit thorough drying. Approximately half of the lot was used each day so all the sheets were in almost continuous service even though some of the beds were not occupied every night.

Each morning the used sheets were collected and sent to the hotel laundry, where they were held until a worker from the Bureau of Home Economics arrived to watch the washing process. A record was kept of the time required for each suds, rinse, extraction, and ironing for every day any of the sheets were washed. Any variation in method was noted on this record.

For the first 4 months the washing procedure was a 15-minute suds, which was started cold and into which the steam was turned after a few minutes' running, 2 hot rinses, each 3 to 5 minutes, and 2 cold rinses, each 3 minutes long. Due to personnel changes in the laundry the method used for the remainder of the time was a cold breakdown of 6 minutes, a hot suds (approximately 160° F.) of 10 minutes, sometimes another suds, depending on the load, 3 hot rinses (120° to 130°) of 3 to 6 minutes each, and 1 or 2 cold rinses (90° to 100°), each 3 to 5 minutes. As it was not possible to control the washing

[14] Acknowledgment is made to Mary Lindsley, manager of the Dodge Hotel, Washington, D.C., for extending the facilities of the hotel for this study, and to Fanny Jeffrey, of the hotel staff, for cooperation in supervising the service and the laundering of the sheets.

temperature automatically, only approximate temperatures are reported.

The first year, a soap solution was used of such concentration that the wheel contained one fourth of a pound of soap chips and one eighth of a pound of soda in 8 to 10 gallons of water. The remainder of the time soap chips alone were used. In accordance with the regular hotel practice, no bleaching was done and bluing was added to the last cold rinse only during a month each spring.

After rinsing, the sheets were extracted 7 to 12 minutes and then ironed, selvage to selvage, through a 4-roller mangle heated with steam at 65 to 70 pounds pressure. The sheets were always folded by hand.

The daily record of the identifying number of each sheet washed was obtained when it was folded. Thus it was possible to determine exactly how many times a given sheet was laundered. A chart was kept for each sheet, breaks being recorded thereon as they occurred. The area, kind of break, and number of washes at which each break appeared were recorded. The sheets were then repaired in the hotel mending room and returned to service.

Ordinary stains were removed by the regular washing or by soaking in the soap tank overnight and then rewashing. This and any other necessary stain-removal treatment was recorded. Sheets for testing were selected at random and of these only two had ever been placed in the soap tank to remove stains.

LABORATORY TESTS [15]

One sheet of each grade of cotton was removed at intervals (table 18) and tested for weight, thread count, thickness, and breaking and bursting strength. All samples were conditioned at least 4 hours before testing in a room maintained at 70° F. and 65 percent relative humidity. Fluidity, copper number, and methylene blue absorption determinations were also made at the same test periods.

SAMPLING

The area, 22 inches wide and 71 inches long, most probably occupied by the body as shown in the diagram given by O'Brien and Steele (*44*) was used for sampling (fig. 11). Breaking-strength determinations were made with strips taken at the places of probable maximum wear, symmetrical to the center line and selected so that no warp or filling threads were duplicated. The sections B, C, and D each supplied 5 warp and 5 filling strips and 3 bursting-strength samples. In addition, the A, B, and C sections each furnished 1 and the D section 2 samples for determining the weight per square yard of the fabric. The middle fold was tested for breaking strength in four places both warpwise and fillingwise. Thickness and thread count were determined on the pieces used for the weight determinations. Sections A, B, C, and D were sampled for the fluidity and copper-number determinations. A composite sample of all four sections was taken for the methylene blue absorptions. The remainder of the sheet was used in the ironing study (see pp. 48 to 64).

---

[15] The assistance rendered by Jeanne D. Guerin, of the Bureau staff, both at the hotel and in the laboratory, is gratefully acknowledged. Doris M. Buchanan, formerly of the Bureau staff, assisted with the chemical determinations.

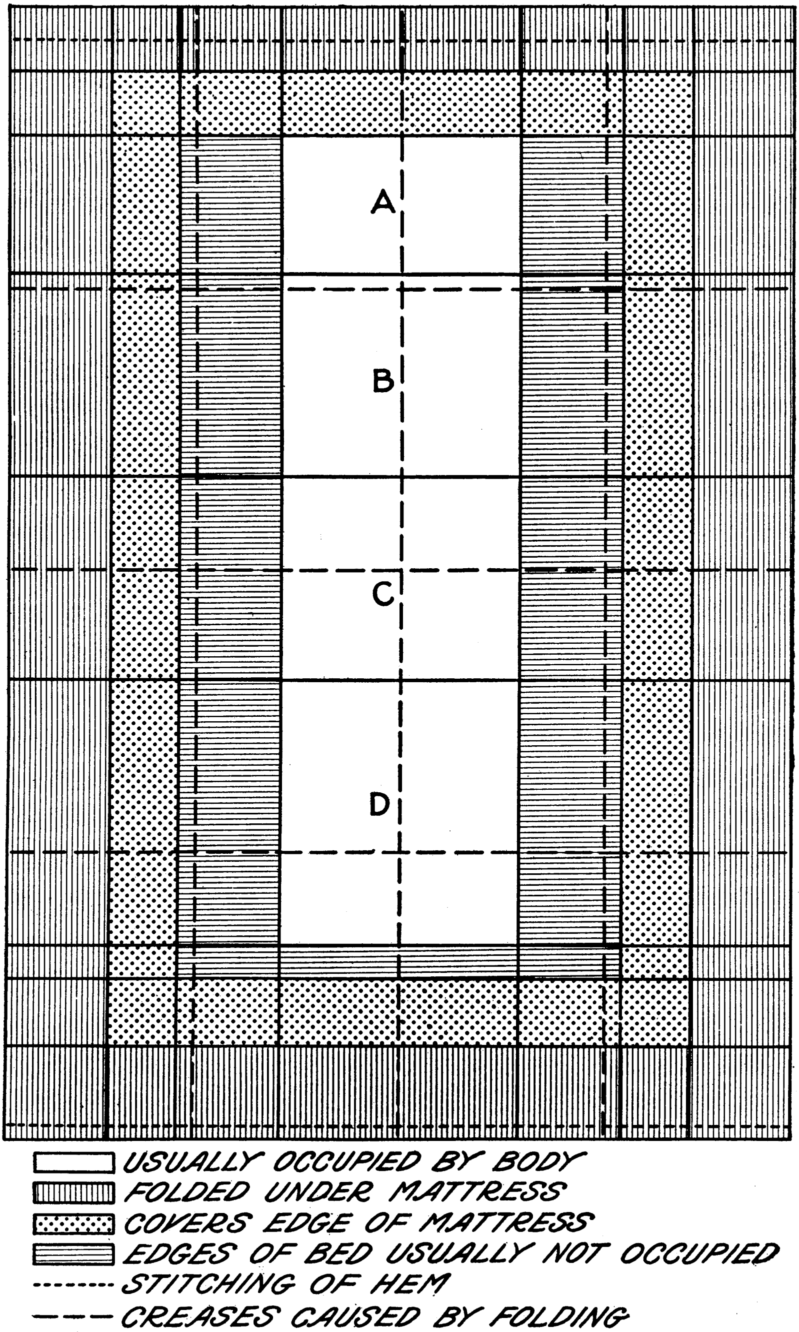

FIGURE 11.—Plan of layout for sampling laundered sheets. The part occupied by the body was tested. Section A is ordinarily occupied by the pillow, section B by the shoulders and back, section C by the hips, and section D by the legs and feet.

At the beginning all tests were made on the new fabric of each grade. In order to study the effect of aging only, two control sheets of each grade of cotton were stored when the others were put into service. Every time a laundered sheet was removed for testing, breaking strength and bursting strength determinations were made on the stored fabric. The samples from these control sheets were selected to be representative of the entire sheet, none being taken closer than 12 inches to the selvage.

WEIGHT, THREAD COUNT, AND THICKNESS

In determining the weight, 2-inch squares were stamped out with a die and weighed on a torsion balance reading directly in ounces per square yard. The number of threads in an inch both warpwise and fillingwise was determined with a thread-counting micrometer. Thickness was measured on the same samples with a micrometer gage graduated to read to 0.001 inch, which exerted constant pressure on a given area of the fabric. In each of these tests, the average of five readings was reported.

BREAKING STRENGTH

The strip method was used for determining the breaking strength of the sheets. In accordance with the method recommended by the Federal Specifications Board (*53*), samples were cut 1¼ by 6 inches and raveled down to exactly 1 inch. The pendulum-type testing machine with a capacity of 150 to 300 pounds was motor driven, the lower jaw traveling down at the rate of 12 inches per minute. The distance between the top and bottom jaws, 3 inches wide both front and back, was 3 inches. Warp and filling specimens were broken and in each case 15 values were averaged.

BURSTING STRENGTH

The steel-ball attachment for the testing machine was used to determine the bursting strength. Samples were cut 4 by 4 inches and the average of nine determinations reported.

SHRINKAGE

Each sheet was measured before going into service and again after being removed. The length was measured in three places and width in five, to the nearest one sixteenth of an inch. The shrinkage was calculated from these measurements.

FLUIDITY IN CUPRAMMONIUM SOLUTION

The fluidity (viscosity) tests were made with solutions of cotton in cuprammonium hydroxide at 25° C. by means of capillary-tube viscometers. Since the details of the method used were developed in connection with the ironing study, the description of the procedure is given on page 53.

The fluidity values were calculated in centimeter-gram-second units by the equation $F=\frac{q}{C(P-p)}$ where F equals the fluidity, C the constant of the instrument, q the rate of flow, and the quantity $(P-p)$ the average pressure causing flow. The value of C is given by the expression $\frac{\pi g d^4}{128L}$, where g is the acceleration of gravity, d is the internal diameter of the capillary tube and L, the length of the capillary. The quantities d and L were 0.1136 and 3.23 centimeters, respectively, for this study. $\frac{q}{P-p}$ is obtained from flow pressure graphs (fig. 17) where the pressure head, P, is plotted as abscissa and the rate of flow, q, as ordinate. The intercept on the pressure axis gives the yield value, p.

COPPER NUMBER

The method adopted was the same as that described in the ironing study (p. 56). Analyses were made with 1.5 grams of the finely divided conditioned material and the results are recorded in grams of copper reduced per 100 grams of dry cotton.

ABSORPTION OF METHYLENE BLUE

The titrimetric method of Clibbens and Geake (*14*) was used, in which the disintegrated material was treated with a buffered methylene blue solution of pH 7. The most worn sheetings absorbed so much methylene blue that 0.3-gram samples were substituted for the 2.5-gram quantities recommended by Clibbens and Geake (*14*). Since methylene blue absorption values may be greatly influenced by the presence of traces of alkali or soap, the materials, previous to the absorption measurements, were steeped for 1 hour in $\frac{N}{10}$ sulphuric acid and then rinsed and steeped in distilled water until the washings were neutral. The absorption is expressed in millimols of methylene blue per 100 grams of dry cotton.

RESULTS

The change in weight of the sheets after the first wash was not appreciable, but there was a gradual loss in weight with service, as shown in table 18. Grade No. 8 (Strict Good Ordinary) was always slightly lighter than grade No. 3 (Good Middling) or grade No. 5 (Middling), and the loss in weight for grade No. 8 at 210 washes was the same as for grades Nos. 3 and 5 after 240 washes. This seems to indicate that after a loss of 20 percent (0.8 ounce, approximately) sheets are no longer serviceable. These three cottons were all made into sheets of medium weight, so no generalization can be made as to what might apply for lightweight or heavyweight sheetings. In the order of increasing weight, the grades ranked Strict Good Ordinary, Middling, and Good Middling.

The values for thread count are also given in table 18. The number of warp threads per inch decreased, while the number of filling threads increased with washing. This change was expected, as the sheets were shrinking in length and stretching in width. All the fabrics showed a trend toward the same number of threads in both warp and filling directions after 125 washes. As shown in this table thickness increased with the first washing due to shrinkage. In all cases the variation in thickness was slight and of the same order as the error in measuring.

TABLE 18.—*Thread count, weight, and thickness, after repeated launderings and wear, for sheetings made from the 3 selected cottons*

Grade of cotton	Test period (times laundered)	Threads per inch		Weight per square yard	Thickness
		Warp	Filling		
	Number	*Number*	*Number*	*Ounces*	*Inches*
Good Middling (No. 3)	[1] 0	[1] 71	[1] 63	[1] 4.07	[1] 0.009
	1	73	63	4.10	.011
	75	70	65	4.02	.011
	125	69	65	3.78	.010
	150	68	67	3.80	.010
	175	70	68	3.78	.010
	200	70	68	3.76	.010
	225	70	69	3.50	.010
	240	70	67	3.34	.010
Middling (No. 5)	[1] 0	[1] 72	[1] 62	[1] 4.01	[1] .009
	1	72	63	3.98	.011
	75	70	67	4.00	.011
	125	70	67	3.76	.010
	150	69	66	3.64	.010
	175	68	67	3.60	.010
	200	69	68	3.74	.010
	225	68	69	3.26	.009
	240	69	70	3.44	.009
Strict Good Ordinary (No. 8)	[1] 0	[1] 71	[1] 61	[1] 3.89	[1] .009
	1	72	63	3.90	.011
	75	68	65	3.70	.011
	125	68	66	3.44	.010
	150	67	64	3.50	.010
	165	69	65	3.38	.009
	175	68	66	3.34	.010
	200	68	66	3.24	.010
	210	68	65	3.12	.010

[1] Average of 2 control sheets.

The average breaking strengths of the B, C, and D sections and middle fold of the sheets after various periods of wear are shown in table 19 and figure 12. In all three grades the breaking strength of the B section was always the lowest, while the C and D sections were of the same order. Contrary to the results of an analysis of sheets previously used at the hotel (*44*), the strength of the middle fold was no lower than that of the section from which it was taken. The Strict Good Ordinary sheets had a lower initial breaking strength, but the general downward trend was the same for all three grades.

The loss in breaking strength as compared with a new sheet of each grade is given in table 20 and plotted in figure 13. The greater loss in the breaking strength of the warp up to 75 washes is probably due to the loss of sizing. A comparison of the loss in strength of sheets washed once and 75 times shows that approximately half the loss in the warp during this interval took place in the first wash as did almost all the loss in the filling.

A laundered sheet would appear relatively stronger as a result of shrinkage. For comparison, therefore, the average breaking strengths were calculated for a 64 by 64 fabric, which was the gray specification (table 21). The index value, the average breaking strength in pounds divided by the average thread count, was computed for both the warp and filling directions (table 22 and fig 14). The strength-weight factor, the sum of the warp and filling breaking strength in pounds divided by the weight per square yard in ounces, is plotted in figure 15. By both methods of comparison, grade No. 5 is higher than 3, which in turn is above 8, except for the inversion of 3 and 5 at 125 and 225 washes.

TABLE 19.—*Breaking strength of various sections of sheetings made from the 3 selected cottons tested after repeated launderings and wear*

Grade of cotton	Test period (times laundered)	Breaking strength [1]									
		Warp					Filling				
		Section			Average	Middle fold	Section			Average	Middle fold
		B	C	D			B	C	D		
	No.	*Lb.*	*Lb*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Good Middling (No. 3)	[2] 0	[2] 61.7	[2] 61.6	[2] 63.8	[2] 62.4	------	[2] 41.5	[2] 42.5	[2] 42.1	[2] 42.0	------
	1	49.4	52.8	53.7	52.0	------	33.3	32.8	33.4	33.2	------
	75	38.1	48.7	48.7	45.2	45.9	30.6	32.5	34.5	32.5	35.1
	125	35.6	40.3	36.6	37.5	34.8	20.1	24.9	26.2	23.7	22.2
	150	29.7	32.5	32.1	31.4	32.3	16.2	18.3	18.6	17.7	20.3
	175	26.2	29.0	29.7	28.3	28.3	12.2	17.0	15.6	14.9	15.8
	200	20.8	27.6	25.9	24.8	27.1	8.3	14.2	13.4	12.0	12.5
	225	17.9	26.4	26.2	23.5	23.0	5.6	13.5	10.8	10.0	9.6
	240	14.1	19.1	22.8	18.7	19.3	3.4	8.6	6.6	6.2	5.1
Middling (No. 5)	[2] 0	[2] 61.2	[2] 59.2	[2] 61.5	[2] 60.6	------	[2] 37.9	[2] 38.7	[2] 39.2	[2] 38.6	------
	1	52.4	49.4	54.5	52.1	------	32.0	33.3	32.0	32.4	------
	75	45.1	47.0	46.2	46.1	49.3	30.2	34.5	33.5	32.7	32.8
	125	31.4	37.7	35.7	34.9	32.9	22.5	22.5	25.7	23.6	22.0
	150	28.9	36.8	36.4	34.0	33.7	16.9	17.6	20.2	18.2	18.8
	175	27.2	28.8	31.2	29.1	32.0	12.4	15.9	16.6	15.0	15.5
	200	22.5	28.8	28.3	26.5	27.3	10.7	13.9	13.2	12.6	10.3
	225	16.5	23.9	23.6	21.3	21.4	4.2	10.4	9.1	7.9	8.6
	240	17.1	24.2	21.5	20.9	20.5	4.9	8.9	6.1	6.6	6.5
Strict Good Ordinary (No. 8)	[2] 0	[2] 49.5	[2] 50.4	[2] 50.9	[2] 50.3	------	[2] 29.1	[2] 30.4	[2] 30.3	[2] 29.9	------
	1	43.3	45.9	45.4	44.9	------	28.8	29.6	27.9	28.8	------
	75	39.2	39.8	38.8	39.3	38.9	27.4	27.6	28.9	28.0	26.5
	125	27.9	30.1	32.0	30.0	29.9	13.8	19.3	18.6	17.2	20.1
	150	24.4	28.6	28.1	27.0	28.2	13.4	15.9	15.7	15.0	15.6
	165	22.8	25.7	24.9	24.5	21.4	9.0	13.3	12.1	11.5	12.8
	175	20.6	25.3	25.1	23.7	24.0	7.9	13.5	12.9	11.4	12.8
	200	14.3	18.1	17.7	16.7	15.0	3.3	7.4	8.8	6.5	8.0
	210	15.1	19.0	17.6	17.2	19.4	5.5	7.8	7.8	7.0	7.4

[1] Strip method.
[2] Average of controls for 8 test periods.

TABLE 20.—*Loss in breaking strength of sheetings made from the 3 selected cottons tested after different intervals of service*

Test period (times laundered)	Loss in breaking strength					
	Good Middling (No. 3)		Middling (No. 5)		Strict Good Ordinary (No. 8)	
	Warp	Filling	Warp	Filling	Warp	Filling
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	16.7	20.9	14.0	16.1	10.8	3.7
75	27.6	22.6	23.9	15.3	21.9	6.4
125	39.9	43.6	42.4	38.9	40.4	42.5
150	49.8	57.9	43.9	52.8	46.3	50.8
165	------	------	------	------	51.4	61.6
175	54.7	64.5	51.9	61.2	52.9	61.9
200	60.3	71.5	56.3	67.4	66.8	78.3
210	------	------	------	------	65.9	76.7
225	62.5	76.2	64.8	79.6	------	------
240	70.2	85.4	65.4	82.9	------	------

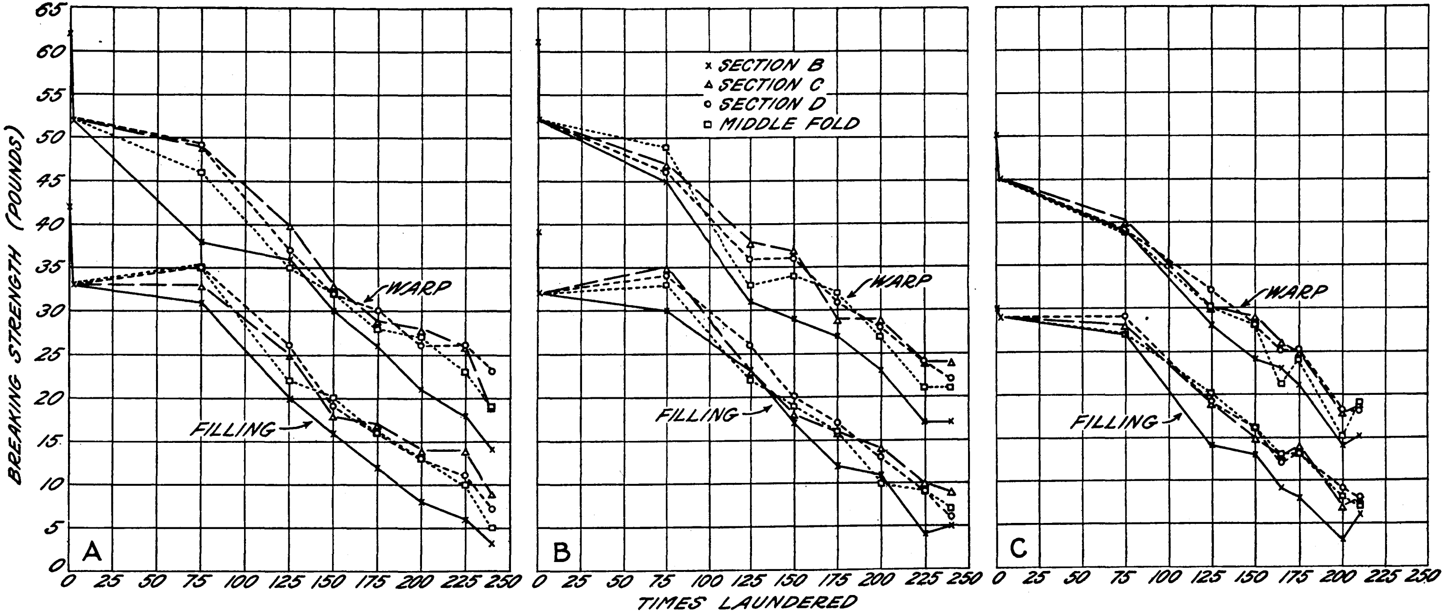

Figure 12.—Breaking strengths of three sections and middle fold of sheetings made from the three special cottons. Tests were made of various intervals during wear life: *A*, Good Middling cotton sheeting; *B*, Middling cotton sheeting; *C*, Strict Good Ordinary cotton sheeting.

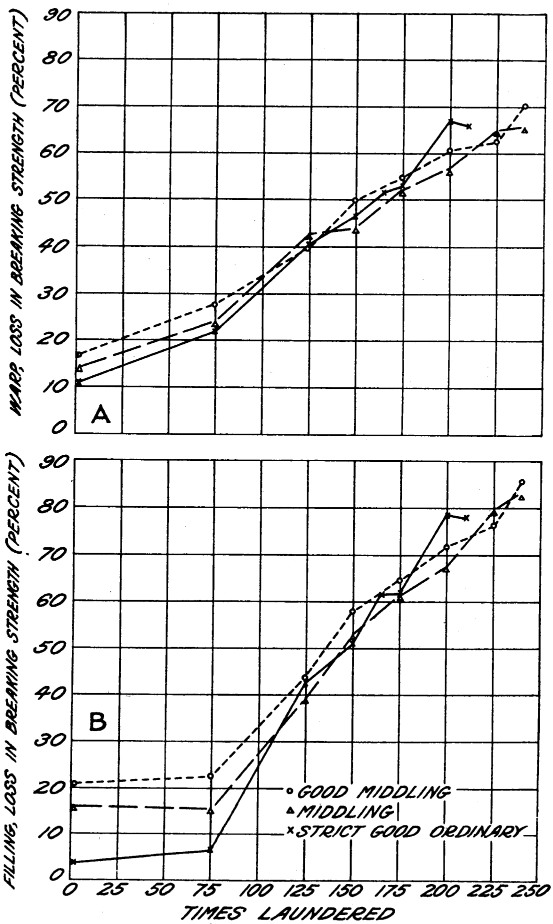

FIGURE 13.—Loss in average breaking strength of laundered sheets made of the three selected cottons: *A*, Warpwise; *B*, fillingwise.

TABLE 21.—*Breaking strength corrected to a 64 by 64 construction for new and laundered sheetings made from the 3 selected cottons*

Grade of cotton	Direction of test	Gray[1]	Bleached[1]	Corrected testing strength for sheets laundered indicated number of times										
				0	1	75	125	150	165	175	200	210	225	240
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Good Middling (No. 3)	Warp	62.0	56.7	56.0	45.8	41.5	34.6	29.5	-----	26.1	22.7	-----	21.8	17.1
	Filling	50.3	42.7	43.0	33.6	31.8	23.3	16.9	-----	14.0	11.3	-----	9.4	5.9
Middling (No. 5)	Warp	59.7	58.0	54.0	46.3	42.4	32.1	31.6	-----	27.2	24.6	-----	20.0	19.2
	Filling	49.8	39.4	39.8	32.9	31.2	22.7	17.8	-----	14.3	11.8	-----	7.6	6.0
Strict Good Ordinary (No. 8)	Warp	51.3	46.4	45.5	40.0	36.8	28.3	25.7	22.7	22.4	15.8	16.2	-----	-----
	Filling	43.1	33.2	31.6	29.4	27.6	16.8	14.7	11.4	11.1	6.3	6.9	-----	-----

[1] Taken from p. 21.

Bursting strength proved to be a somewhat inaccurate test, as there was considerable variation in the individual values, particularly on sized fabrics. The values in the respective grades after 1 and after 75 washes are within the range of the values for the controls as determined at different test periods. There was, however, a continual drop in bursting strength after 75 washes. This is shown more clearly in figure 16, in which the values of table 23 are plotted. There is a correlation between bursting strength and fabric failure. Breaks appeared when the bursting strength was approximately 28 pounds. This occurred at 125 washes for Strict Good Ordinary, 165 washes for Good Middling, and 175 washes for Middling cotton, and corresponds to the average time of first break, as shown in table 24.

TABLE 22.—*Index, shrinkage, and strength-weight factor for new and laundered sheetings made from the 3 selected cottons*

Grade of cotton	Test period (times laundered)	Index [1]		Shrinkage		Strength-weight factor [2]
		Warp	Filling	Warp	Filling	
	Number			*Percent*	*Percent*	
Good Middling (No. 3)	[3] 0	[3] 0.87	[3] 0.67	------	------	[3] 25.7
	1	.72	.53	−3.1	−1.1	20.8
	75	.65	.50	−6.4	+4.4	19.4
	125	.54	.36	−7.4	+3.7	16.2
	150	.46	.26	−6.7	+6.0	12.9
	175	.41	.22	−7.2	+4.2	11.4
	200	.36	.18	−7.5	+4.1	9.8
	225	.34	.15	−7.6	+4.7	9.6
	240	.27	.09	−5.3	+0.7	7.5
Middling (No. 5)	[3] 0	[3] .84	[3] .62	------	------	[3] 24.8
	1	.72	.51	−3.0	+0.2	21.2
	75	.66	.49	−6.5	+4.0	19.7
	125	.50	.35	−7.1	+4.4	15.6
	150	.50	.28	−7.3	+5.3	14.3
	175	.43	.22	−7.0	+5.3	12.3
	200	.39	.18	−7.8	+5.2	10.5
	225	.31	.12	−7.6	+4.0	9.0
	240	.30	.09	−6.9	+3.6	8.0
Strict Good Ordinary (No. 8)	[3] 0	[3] .71	[3] .49	------	------	[3] 20.3
	1	.63	.46	−2.8	−0.3	18.9
	75	.58	.43	−6.5	+4.5	18.2
	125	.44	.26	−6.7	+4.7	13.7
	150	.40	.23	−6.8	+5.4	11.9
	165	.35	.18	−5.2	+3.0	10.7
	175	.35	.17	−7.2	+6.7	10.5
	200	.25	.10	−8.0	+4.9	7.2
	210	.25	.11	−7.9	+5.3	7.8

[1] $\text{Index} = \frac{\text{average breaking strength in pounds}}{\text{average thread count.}}$

[2] $\text{Strength-weight factor} = \frac{\text{W breaking strength in pounds} + \text{F breaking strength in pounds}}{\text{Weight per square yard in ounces.}}$

[3] Average of controls for 8 test periods.

TABLE 23.—*Bursting strength of sheetings made from the 3 selected cottons, tested after repeated launderings and wear*

Test period (times laundered)	Bursting strength			Test period (times laundered)	Bursting strength		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)		Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
0 [1]	[1] 54.6	[1] 55.0	[1] 38.2	175	25.3	27.9	20.4
1	55.1	56.3	40.6	200	22.8	23.7	14.6
75	53.6	56.3	44.7	210	------	------	13.6
125	36.1	41.9	28.9	225	22.6	20.9	------
150	31.8	35.4	25.7	240	11.6	16.9	------
165	------	------	17.8				

[1] Average of controls for 8 test periods.

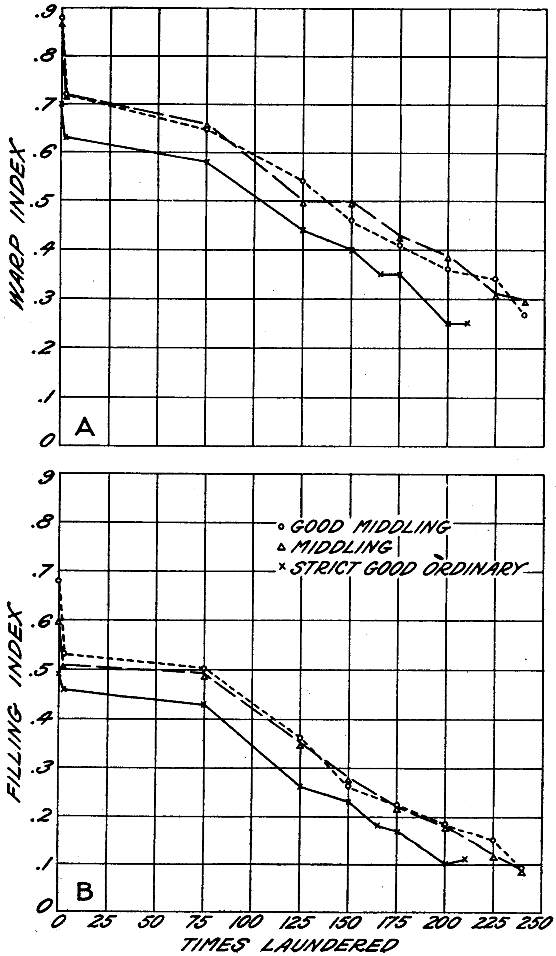

FIGURE 14.—Index $\left[\frac{\text{average breaking strength}}{\text{average thread count}}\right]$ for sheetings made of the three selected cottons and given various amounts of wear: *A*, Warpwise; *B*, fillingwise.

TABLE 24.—*Range, average, and standard deviation of time of first break, and time of removing from service for sheets made of the 3 selected cottons*

Grade of cotton	First break occurred			Removed from service	
	Range (times laundered)	Average [1] (times laundered)	Standard deviation σ	Range (times laundered)	Average [2] (times laundered)
	Number	*Number*		*Number*	*Number*
Good Middling (No. 3)	123–198	166	18	222–251	237
Middling (No. 5)	137–205	180	15	223–252	239
Strict Good Ordinary (No. 8)	102–177	145	20	197–217	208

[1] Average of 26 sheets. [2] Average of 24 sheets.

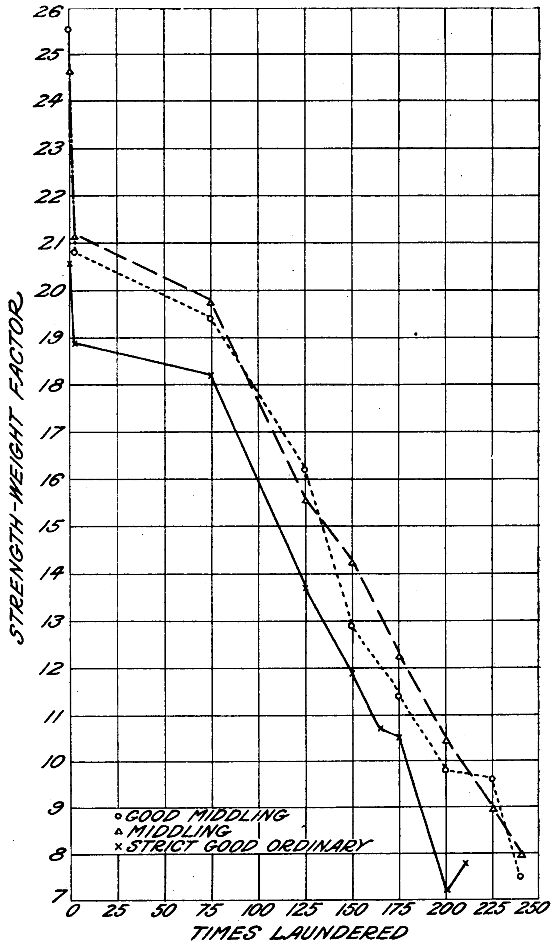

FIGURE 15.—Strength-weight factor $\left[\frac{\text{warp breaking strength} + \text{filling breaking strength}}{\text{weight per square yard}}\right]$ for sheetings made of the three selected cottons, removed from service at intervals of their wear life.

The shrinkage for sheets removed from service is shown in table 25, and indicates that after 75 washes the change in dimensions was very slight. Apparently the gain in width was caused by always ironing from selvage to selvage. This agrees with the observations of McClew (*35*). The change in area is slightly greater than that reported by the Cotton Textile Institute (*5*). The variation in shrinkage for the three different fabrics is not significant.

TABLE 25.—*Average shrinkage of sheetings*[1] *made from the 3 selected cottons*

Grade of cotton	Length	Width	Area
	Percent	*Percent*	*Percent*
Good Middling (No. 3)	−7.7	+3.0	−4.9
Middling (No. 5)	−7.9	+3.7	−4.4
Strict Good Ordinary (No. 8)	−7.6	+4.1	−3.7

[1] Average of 30 sheets.

None of the controls of all grades which were stored showed a loss in breaking strength during storage. Any variations noted in the breaking strength were of the same order as those due to sampling. The difference between the values at the beginning of the study and the average value of the controls in each case is insignificant. Bursting strength does not show any variation that can be attributed to the effects of storing.

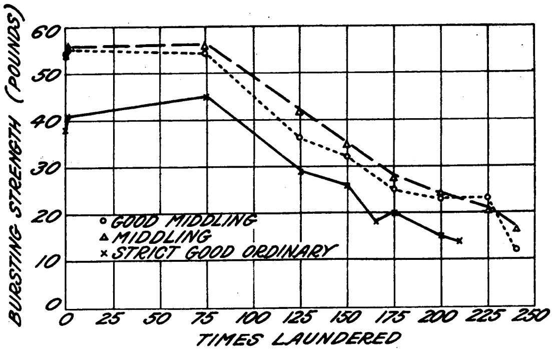

FIGURE 16.—Bursting strength of laundered sheetings made from the three selected cottons.

The life of the sheets as measured by the number of times laundered is given in table 24. The six of each grade used for testing are not included. When, in the judgment of the workers, the sheets were too weak to darn or patch, they were removed from service. Since this personal element was involved, the distribution of the time of first break was also studied and is reported in table 24. This first break may have been due to accident as well as actual wear. However, a study of the life of the sheets and the time of first break shows that the Middling cotton wore slightly better than Good Middling and both of these outlasted the Strict Good Ordinary cotton.

A summary of the record charts showing the location and types of breaks indicates that the maximum wear occurred in the B section and at the selvages for all three grades. The majority of breaks were due to the failure of the filling yarns. Since the sheets were put through the mangle crosswise, creases resulted parallel to the selvages. This weakened the material so that in most cases the selvages were removed eventually and the sheets hemmed. In some instances breaks even occurred along these hems.

The values for the fluidity test, which is a measure of deterioration in cotton, are given in table 26 for the three sheetings. The results show that initially the Good Middling and Middling cottons are of the same order but that the Strict Good Ordinary is weaker. In the case of all three of the selected cottons there is a significant increase in fluidity with service. The appreciable rise in this quantity after the first wash may be attributed to partial removal of starch and other sizing materials. The values for the Strict Good Ordinary cotton indicate that the variation between sheets may be greater than the amount of tendering resulting from 10 washes.

Flow-pressure relationships for the cuprammonium solutions of the three sheetings are illustrated in figure 17 where average rates of flow for the four sections are plotted. The slopes of the lines increase with fluidity, since rate of flow is used as the ordinate. The lines of least slope in each set of diagrams represent the material after one wash; the lines of steeper slope, the material at intervals during the period of service. The steepest line for the Good Middling and Middling groups gives the flow-pressure relationship for the materials laundered 225 times, and that for the Strict Good Ordinary, after 200 washes. The latter is steeper than the two former, showing that the Strict Good Ordinary cotton is more tendered at the end of 200 washes than are the other cottons at the end of 225. Two hundred washings for Strict Good Ordinary and 225 for the other two sheetings are within the range of removal from service, as shown by table 24.

TABLE 26.—*Fluidity measurements of various sections of sheets made from the 3 selected cottons and removed from service at intervals during their wear life*

Grade of cotton	Test period (times laundered)	Fluidity				
		Section A	Section B	Section C	Section D	Average
	Number	*Reciprocal poises*	*Reciprocal poises*	*Reciprocal poises*	*Reciprocal poises*	*Reciprocal poises*
Good Middling (No. 3)	[1] 0					[1] 12.1
	1					13.1
	75	14.5	14.9	14.2	14.2	14.5
	125	15.3	15.5	15.3	15.2	15.3
	150	17.3	17.5	17.4	17.1	17.3
	175	18.2	18.5	17.7	17.9	18.1
	200	18.8	19.0	18.4	18.2	18.6
	[2] 225	18.7	19.1	18.4	18.2	18.6
	240	20.2	20.7	20.2	19.5	20.2
Middling (No. 5)	[1] 0					[1] 12.2
	1					12.6
	75	15.0	15.5	14.9	14.9	15.1
	125	15.8	15.9	15.4	15.3	15.6
	150	17.2	17.6	17.1	17.1	17.3
	175	17.6	18.2	18.0	17.4	17.8
	200	18.4	18.8	18.4	18.3	18.5
	225	19.6	19.9	19.5	19.2	19.6
	240	20.3	20.9	20.1	19.9	20.3
Strict Good Ordinary (No. 8)	[1] 0					[1] 13.3
	1					14.4
	75	15.3	15.4	15.2	15.3	15.3
	125	16.4	16.5	16.3	16.1	16.3
	150	17.2	17.5	17.4	17.2	17.3
	165	17.9	18.7	18.2	18.0	18.2
	175	18.4	18.7	18.3	17.9	18.3
	200	20.5	21.4	20.5	20.2	20.7
	[2] 210	19.8	20.4	19.7	19.6	19.9

[1] Average of 2 sheets.
[2] The results of all the chemical and physical tests made on the sheet removed for testing at this period showed that the sample did not conform to the general trend for the grade.

The yield value, as given by the intercept on the pressure axis is an index to the abnormality of a solution. This value becomes smaller as the fabric of each grade becomes more tendered. Thus, with increasingly severe deterioration of the cotton, the cuprammonium solutions approach the normal behavior of viscous liquids. The yield value also decreases according to the grade of cotton in the order Good Middling, Middling, and Strict Good Ordinary. During approximately the last third of the wear life the yield value is zero.

The fluidity relationship by grade is also illustrated graphically in figure 18, where the average of the four sections is plotted against the number of times laundered. This figure shows that throughout

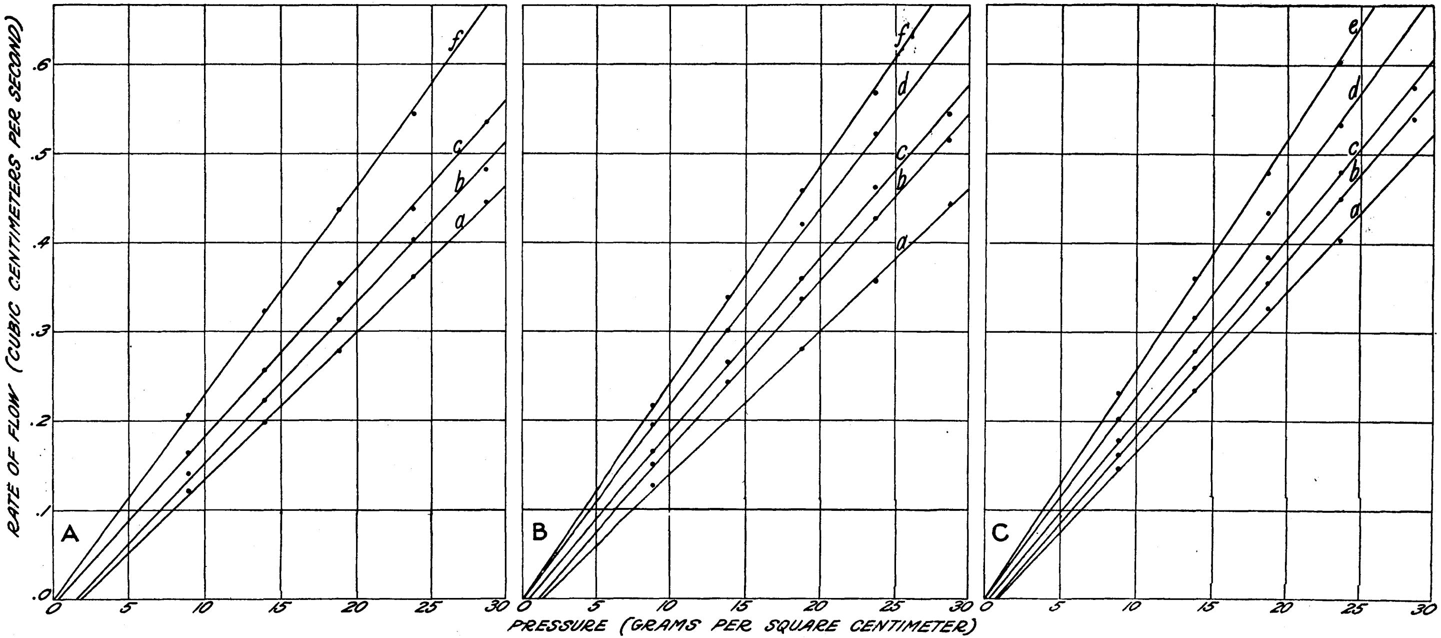

Figure 17.—Flow-pressure relationships for cuprammonium solutions of cotton sheetings removed from service at intervals during their wear life: *A*, Good Middling cotton; *B*, Middling cotton; *C*, Strict Good Ordinary cotton; *a*, once; *b*, 75 times; *c*, 125 times; *d*, 175 times; *e*, 200 times; *f*, 225 times laundered.

the period of observation the fluidity values are higher for sheetings made of Strict Good Ordinary cotton than for those made of the other two cottons. Middling and Good Middling cotton are of the same order.

The fluidity measurements recorded in table 26 for each of the three grades of cotton are plotted by sections of the sheet in figure 19. The order of increasing deterioration of the sections for each

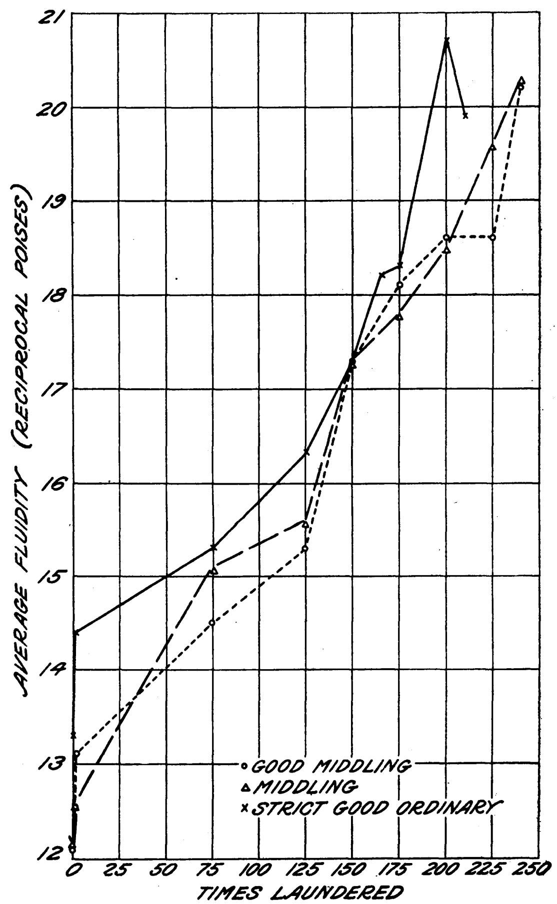

FIGURE 18.—Fluidity values of cuprammonium solutions of sheetings made from the three selected cottons and given different numbers of launderings.

grade is D, C, A, and B. This relationship is shown more clearly in figure 20, where average values of the three cottons are plotted. The greatest difference exists between sections A and B. Section D is superior to section C, which is only slightly superior to section A.

Since section B received the most severe wear, and section D the least, the difference between their fluidity values gives some indication of the wear factor by itself. This difference averages 9 percent of the total rise in fluidity. It would, of course, be greater if section D had not been worn at all, and much greater if the ratio of the number of launderings to the number of nights used were changed from 1 : 1 to 1 : 7 to conform to usual home practice. This is contrary to the opinion expressed in the report of Millard's work (*1*) that the wear factor is negligible in sheets used in hospitals.

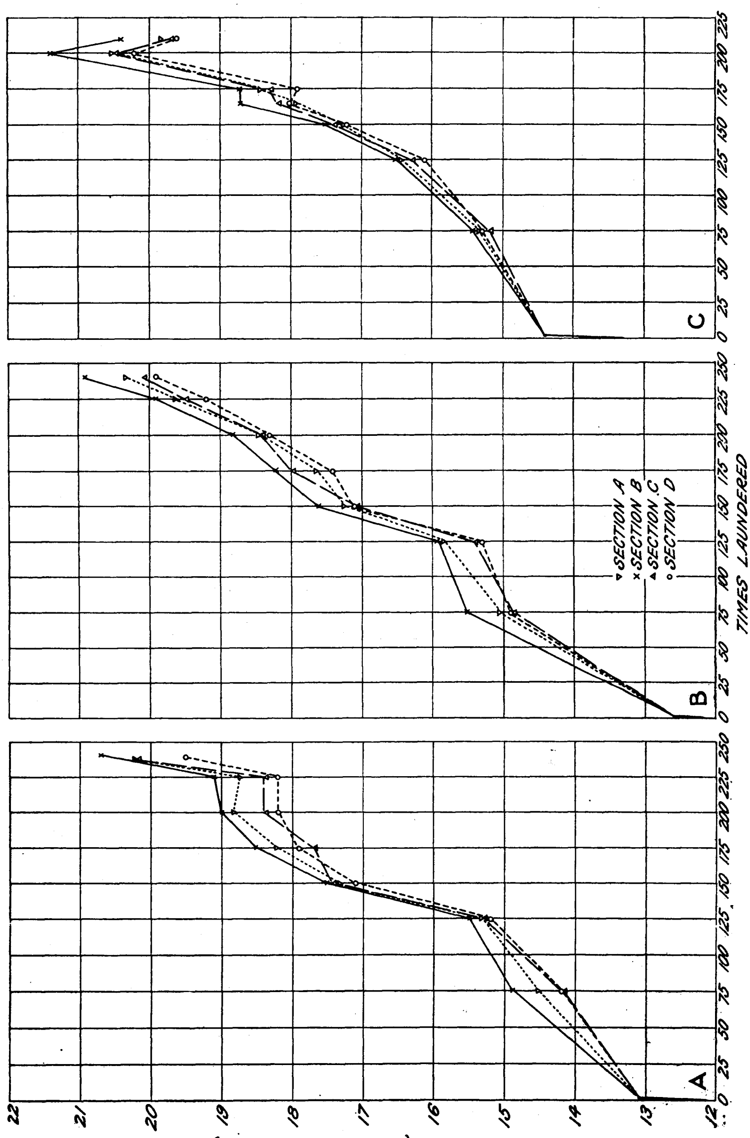

FIGURE 19.—Fluidity values of cuprammonium solutions of different sections of cotton sheetings, which were removed from service at intervals during their wear life: *A*, Good Middling cotton; *B*, Middling cotton; *C*, Strict Good Ordinary cotton.

Deterioration as measured by fluidity appears to be more rapid in the last half of the wear life than in the first half. This is illustrated clearly in figure 20.

In figure 21 the fluidity values are plotted against loss in warp-breaking strength. The graph shows the existence of a linear relationship between these two quantities. This is also the finding when fluidity measurements are plotted against loss in breaking strength of the filling. Clibbens and Ridge (*16*), who progressively modified cotton yarns by the action of oxidizing agents and acids, found a similar correlation between fluidity and tensile strength.

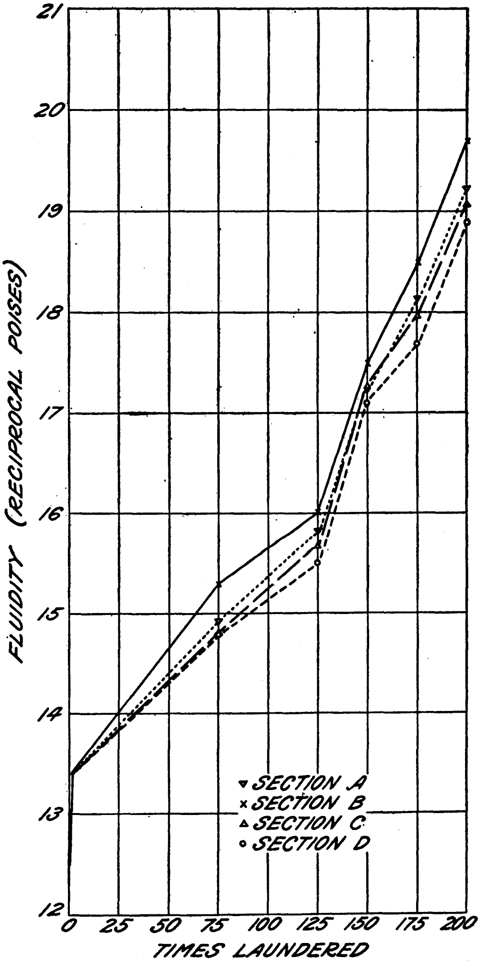

FIGURE 20.—Fluidity values of cuprammonium solutions of different sections of cotton sheetings laundered various numbers of times. The value for each section is the average for sheetings made of the three cottons.

The copper numbers for all three cottons are given in table 27. They also increase steadily with service. Since copper numbers measure chemical deterioration, it is evident that wear produces a progressive chemical deterioration. Again it is apparent that Strict Good Ordinary cotton showed slightly more degradation before it was laundered and at the end of 200 washings than did the other cottons at the end of 225 washings. However, during the major part of its wear life the Good Middling contained more oxidized cellulose than either of the other cottons.

In figure 22 the values for copper numbers given in table 27 are plotted by sheet sections. The degree of chemical degradation of

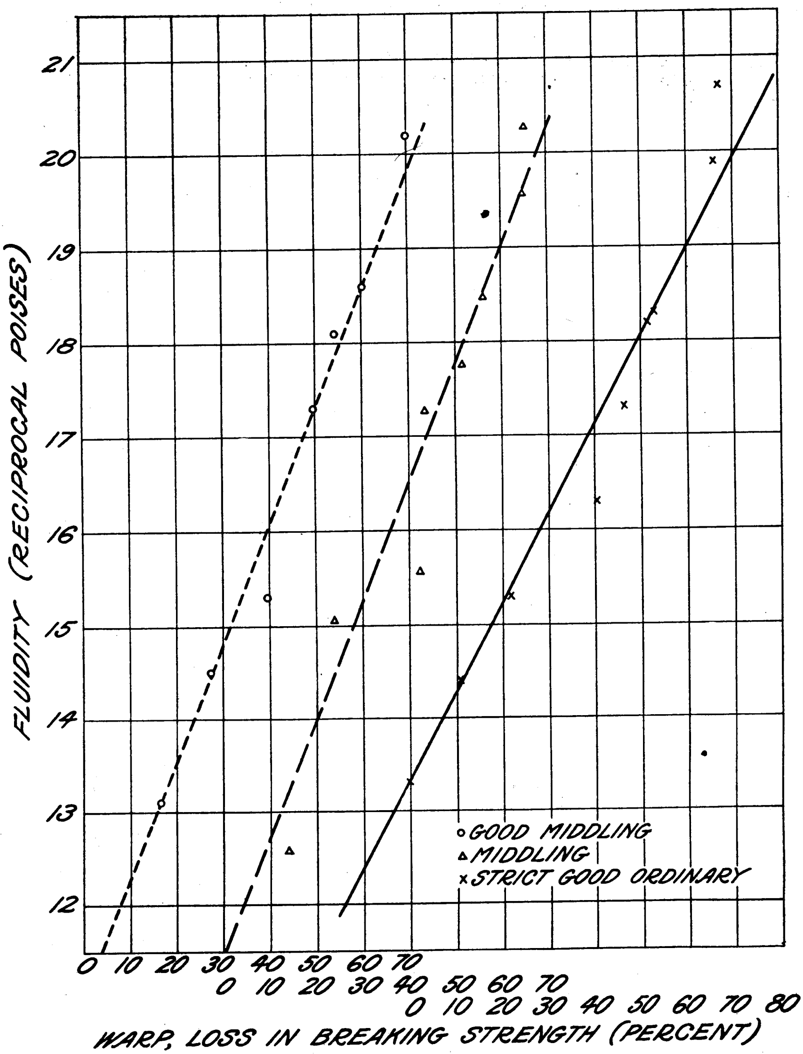

FIGURE 21.—Relationship between the fluidity in cuprammonium solution and the loss in warp breaking strength as compared with a new sheet of each grade. The sheetings were made from the three selected cottons and given various amounts of wear.

all of the fabrics increases in the order, sections D, C, A, and B. This relationship, which is the same as that obtained with the fluidity measurements, is more apparent when the average values of the three grades are plotted, as in figure 23. The increased deterioration of B over that of the other three sections is more evident from copper numbers than from fluidity results. The average difference in copper numbers between B and D amounts to 9½ percent of the total rise in this value, showing again that wear alone is significant. For both fluidity and copper number this percentage difference decreases in the order Good Middling, Middling, and Strict Good Ordinary.

TABLE 27.—*Copper numbers of various sections of sheets made from the 3 selected cottons and removed from service at intervals during their wear life*

Grade of cotton	Test period (times laundered)	Copper number of—				
		Section A	Section B	Section C	Section D	Average
	Number					
Good Middling (No. 3)	[1] 0					[1] 0.29
	1					.38
	75	0.54	0.62	0.51	0.51	.55
	125	.72	.78	.70	.66	.72
	150	.79	.81	.81	.81	.81
	175	.89	.93	.87	.87	.89
	200	.90	.93	.91	.89	.91
	[2] 225	.82	.85	.78	.78	.81
	240	.94	.95	.91	.90	.93
Middling (No. 5)	[1] 0					[1] .29
	1					.36
	75	.53	.53	.51	.52	.52
	125	.62	.67	.57	.57	.61
	150	.73	.76	.71	.68	.72
	175	.77	.80	.79	.75	.78
	200	.85	.92	.85	.80	.86
	225	.86	.94	.90	.85	.89
	240	.90	.96	.90	.89	.91
Strict Good Ordinary (No. 8)	[1] 0					[1] .32
	1					.39
	75	.48	.53	.49	.48	.50
	125	.60	.63	.60	.58	.60
	150	.69	.75	.67	.66	.69
	165	.77	.80	.76	.79	.78
	175	.77	.81	.75	.75	.77
	200	.94	.94	.93	.92	.93
	[2] 210	.86	.91	.88	.86	.88

[1] Average of 2 sheets.
[2] The results of all the chemical and physical tests made on the sheet removed for testing at this period showed that the sample did not conform to the general trend for the grade.

When copper numbers for each grade of cotton are plotted against loss in breaking strength of the warp, the relationship is approximately linear, as in the correlation of fluidity measurements and breaking strengths given in figure 21. Again, when fluidity values are plotted against copper numbers an approach to a linear relation is apparent over the range studied. For all three grades, at any test period, the difference (expressed in percent) in the copper numbers of the laundered and unlaundered materials was about four times the difference in the fluidity results.

The methylene blue absorption values (table 28 and fig. 24) show that absorption increases progressively with wear. Increased absorption indicates chemical deterioration. The absorption is greater for the Strict Good Ordinary cotton after 200 washes than for the other grades after 225 washes. However, for the major part of the wear life, the order of increasing absorption is Strict Good Ordinary, Middling, and Good Middling. These findings are similar to those obtained with the copper number test.

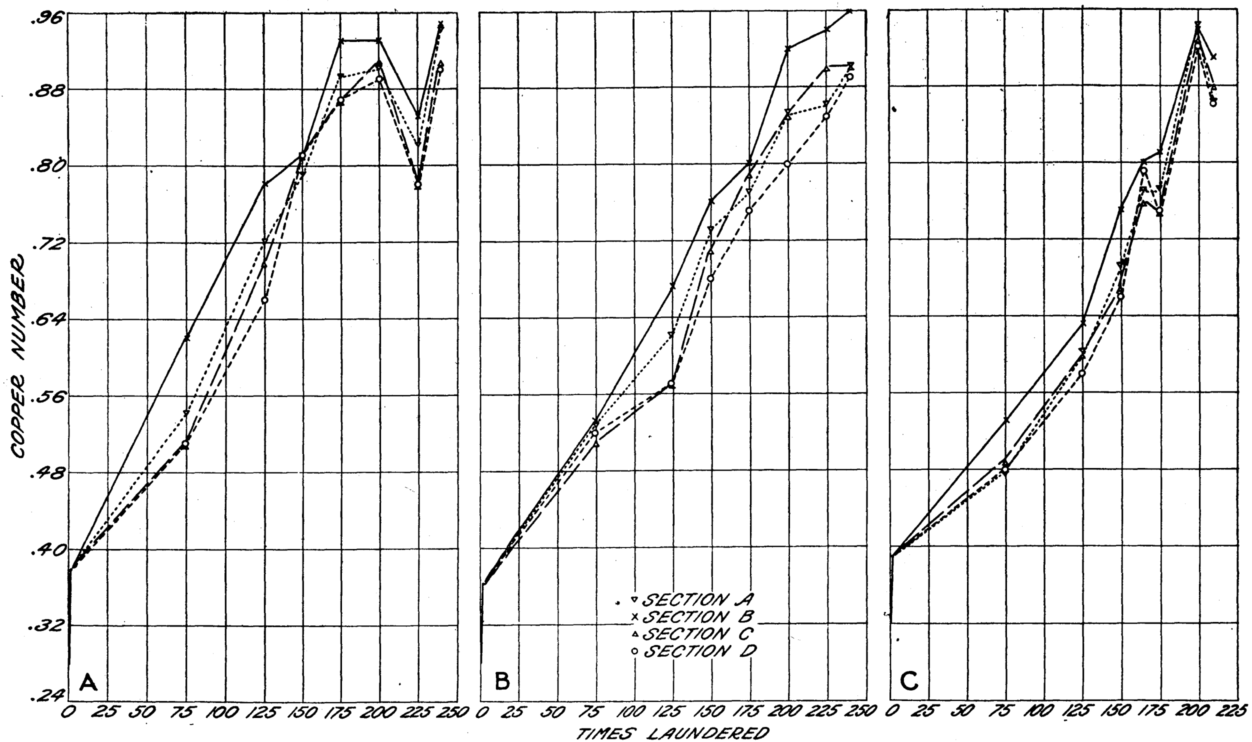

FIGURE 22.—Copper numbers of different sections of cotton sheetings, which were removed from service at intervals during their wear life: *A*, Good Middling cotton; *B*, Middling cotton; *C*, Strict Good Ordinary cotton.

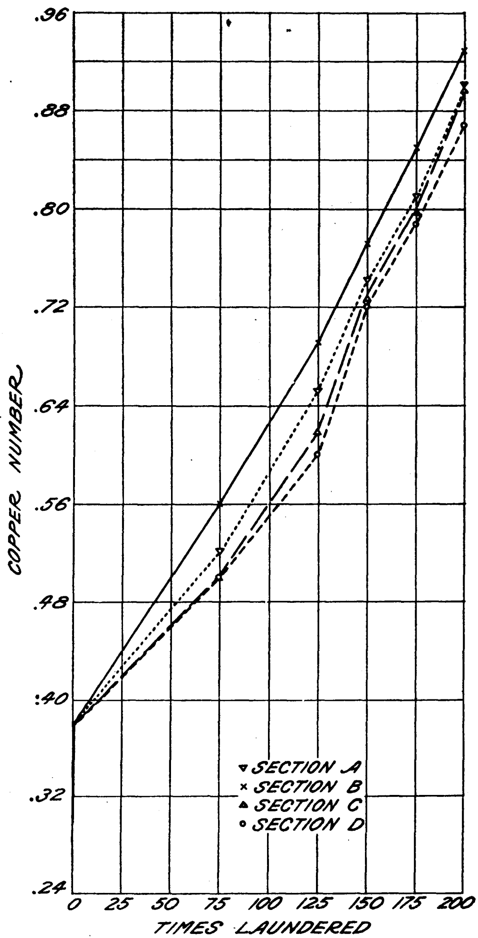

FIGURE 23.—Copper numbers of different sections of cotton sheetings laundered various numbers of times. The value for each section is the average of that for sheetings made of the three cottons.

TABLE 28. *Methylene blue absorption of sheetings made from the 3 selected cottons, tested after repeated launderings and wear*

Test period (times laundered)	Methylene blue absorption			Test period (times laundered)	Methylene blue absorption		
	Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)		Good Middling (No. 3)	Middling (No. 5)	Strict Good Ordinary (No. 8)
0 [1]	[1] 1.88	[1] 1.87	[1] 1.82	175	14.87	14.69	13.02
1	2.48	2.45	2.12	200	15.97	15.88	17.69
75	7.54	7.09	6.85	210			[2] 17.60
125	10.42	10.05	9.17	225	[2] 15.72	17.05	
150	12.80	12.78	12.18	240	17.66	17.54	
165			13.14				

[1] Average of 2 sheets.
[2] The results of all the chemical and physical tests made on the sheet removed for testing at this period showed that the sample did not conform to the general trend for the grade.

Increases in methylene blue absorption were obtained in this study as a result of wear, while in the ironing project the absorption was found to decrease as the temperature rose. At the higher temperatures, however, the rate of this decrease became smaller and the absorption tended toward a limiting value. Barr and Hadfield (*7*), who exposed cotton fabrics to the action of sunlight, found that with exposure the methylene blue absorption decreased somewhat at first

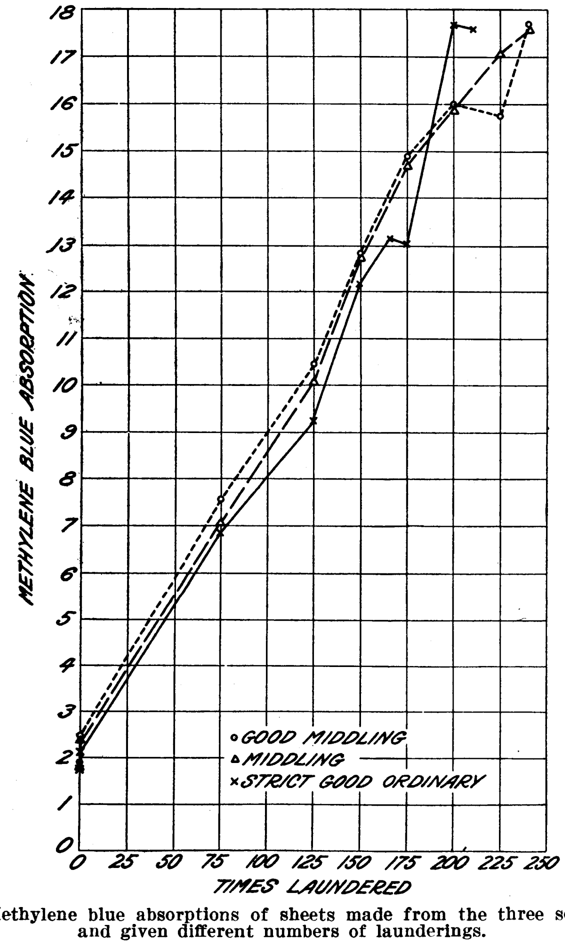

FIGURE 24.—Methylene blue absorptions of sheets made from the three selected cottons and given different numbers of launderings.

and then began to rise. Thus it is obvious that methylene blue absorption is not always a reliable quantitative test for the early stages of oxidation. Taken together with copper number, however, it affords diagnosis of the type of degradation that has occured.

Birtwell, Clibbens, and Ridge (*9*) differentiate between two types of " oxycellulose ", one characterized by a large increase in methylene blue absorption and a relatively small increase in copper number with progressive modification, and the other, the reducing type, by the reverse properties. They obtained the first type by treating cotton with alkali hypobromite. The present study shows that wear and laundering also produce this type of oxidation product since rapid increases in methylene blue absorption and small increases in copper numbers were observed.

CONCLUSIONS

Sheets composed of American upland cotton selected to represent the Good Middling, Middling, and Strict Good Ordinary grades were subjected to controlled wear and laundering. The chemical and physical characteristics of the sheets were determined at intervals during their wear life.

The physical tests indicate that the sheetings of Strict Good Ordinary cotton were weaker initially and throughout their wear life than those made of Middling and Good Middling cotton and were slightly more deteriorated at the end of 200 washings than were the others at the end of 225 washings.

As measured by copper number and methylene blue absorption determinations, the cellulose of the Strict Good Ordinary cotton showed less degradation throughout the major part of the wear life of the sheets than did the cellulose of the Middling and Good Middling cotton. However, at 200 washings, when the sheets of Strict Good Ordinary cotton were worn out the cellulose was slightly more deteriorated than was that of the other two cottons at the end of their service after 225 washings.

Both chemical and physical tests showed that the maximum wear on the sheets occurred in the section occupied by the shoulders. There was no increased wear on the middle fold.

Three and one half years' storage caused no deterioration in unused sheets.

The type of oxidation product characterized by greatly increased affinity for methylene blue was formed as a result of wear and laundering.

EFFECTS OF IRONING TEMPERATURES UPON THE FABRICS [16]

By K. MELVINA DOWNEY and RUTH E. ELMQUIST

As part of a study of the reaction of various grades and varieties of cotton to wear and laundering, data are being accumulated by the Bureau of Home Economics on the physical and chemical changes which take place during ironing in fabrics woven of known grades of cotton. Such information assists in evaluating these grades in terms of the usefulness of the finished fabric and also in formulating recommendations for laundering procedures. Methods of analysis sensitive to small amounts of damage have been used, as well as strength tests which measure more obvious deterioration. This is particularly desirable as the repeated use of high temperatures just below those giving changed measurements for breaking strength may result in an unexpectedly shorter wear life for the fabric.

Experiments in which cotton has been subjected to moderate heat over prolonged periods of time have been described by such ob-

[16] Grateful appreciation is expressed to Doris M. Buchanan, who has given valuable assistance during this investigation. Judith L. Steele has also given aid in compiling data and Jeanne D. Guerin in making breaking-strength tests.

servers as Fort (*19*), Schüler (*48*), Knecht (*32*), Justin-Mueller (*30*), Bain (*6*), Möllering (*37*), Tiltman and Porritt (*50*), Akahira (*2*), Patel (*46*), and Ramsbottom (*47*). The results of these and similar studies are not applicable to ordinary ironing procedures where higher temperatures are applied to only one side of a fabric for a very short time. Even in the reports of ironing studies from which some recommendations have been made to the laundry trade, there has been no indication of work on known grades of cotton under controlled conditions of pressure and moisture. In all cases scorch was detected merely by color change visible to the eye under ordinary lighting conditions, and breaking strength appears to be the only measure recorded of deterioration in the ironed cotton.

Some work with hand irons has been described by Fort (*19*), Knecht and Muller (*33*), and Gilmore (*23*). Since the term scorch has been defined so qualitatively in the published reports of these observers, it is difficult to compare their results. Fort, as well as Knecht and Muller, made comparative temperature observations by means of a thermometer inserted in the iron from the top. Their reports are vague as to the ironing conditions when the danger point for cotton was reached. Gilmore, who worked with an electrically heated hand iron, states that there was visible yellowing on bleached cotton materials without accompanying loss in breaking strength. However, Clayton (*13*, *29*) who subjected such fabrics to a heating plate at various temperatures reports that he obtained a loss in tensile strength at temperatures far below those causing visible scorch. This apparent contradiction may be attributed to differences in moisture content according to the experimental results of Knecht and Muller (*33*), or it may be due to difference in the time of contact with the heated surface. In Gilmore's work the time of contact was 5 seconds and in Clayton's 30 seconds.

In the present investigation the fabrics used were made under experimentally controlled conditions from selected cottons representative of known grades. They were ironed under controlled conditions of moisture, pressure, and temperature with a household ironer (fig. 25), in which a padded roll turns against a heated metallic shoe.[17] With the partial spectrophotometric method used for detecting color change in the ironed materials, it was possible to note measurable effects for ironing temperatures considerably lower than those at which there was visible yellowing in ordinary daylight. Tests were made on the ironed cotton samples not only for losses in breaking strength but also for changes in the chemical nature of the cloth.

ANALYSIS OF DESIZED SHEETINGS

The preparation and construction of the materials used in this study are described on page 3 and the results of the wearing tests to which the finished sheetings were subjected on page 29. They were woven of Good Middling, Middling, and Strict Good Ordinary cotton respectively. The finishing process included a soda kier-boil and chemicking with a one fourth of 1 percent available chlorine solution.

[17] This ironer was supplied through the courtesy of the Apex Electrical Manufacturing Co.

Ironing studies were made on the new sheetings and also on used ones removed from service at various intervals during their wear life. Before being submitted to the heat tests, the new sheets which had been treated in the finishing plant with a mixture of corn starch and a saponified tallow softening material, were desized as follows: The fabric was given a preliminary soaking and rinsing in water at 90° to 100° F. It was then washed in a solution of neutral soap in the temperature range 140° to 150° and rinsed in hot distilled water until the pH of the rinse water was the same as that of the distilled water used. This was followed by two separate enzymic treatments under controlled temperature conditions with thorough rinsing after

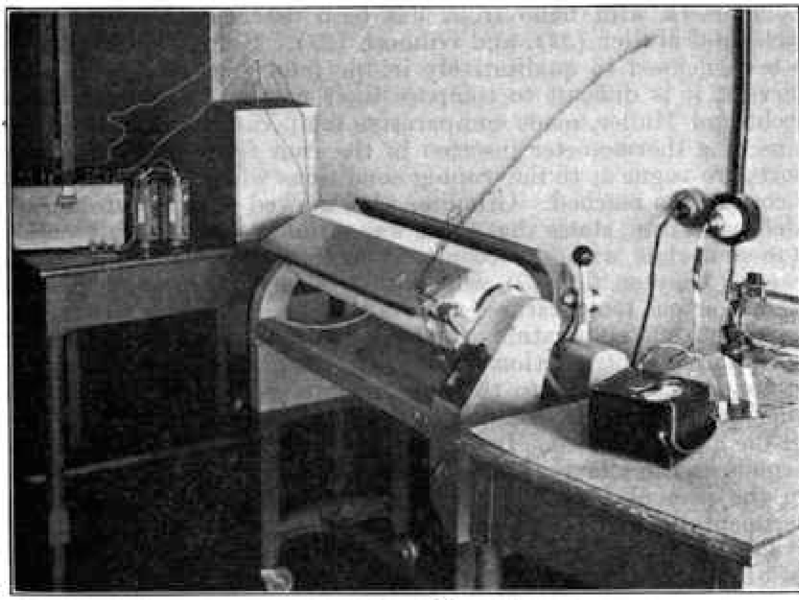

FIGURE 25.—Experimental ironing equipment.

each treatment. The material was finally washed again and rinsed until the pH of the wash liquor was the same as that of the distilled water.

Loss in weight due to this desizing was determined by weighing fringed and thoroughly conditioned samples under standard atmospheric conditions (65 percent relative humidity and 70° F.). This loss ranged from 4.2 to 4.8 percent for all three sheetings. The fat and wax content of the desized fabrics, as determined by extraction with carbon tetrachloride according to the general procedure of Clifford, Higginbotham, and Fargher (*17*), varied from 0.35 to 0.42 percent. Tests for chlorides and sulphates gave negative results. These tests were made because such salts would produce abnormal tendering of the cotton under the influence of heat.

The weight per square yard, thickness (as measured with a micrometer thickness gage exerting a constant pressure), and thread count of the new desized sheetings are given in table 29.

TABLE 29.—*Weight, thickness, and thread count of desized sheetings made from the 3 selected cottons*

Grade of cotton	Weight	Thickness	Thread count	
			Warp	Filling
	Ounces per square yard	*Inches*		
Good Middling (No. 3)	4.1–4.2	0.0113–0.0123	73	66
Middling (No. 5)	4.0–4.2	.0110– .0120	73	65
Strict Good Ordinary (No. 8)	3.8–4.0	.0105– .0118	72	64

IRONING EQUIPMENT AND PROCEDURE

An especially constructed household ironer having a roll 26 inches long and 7 inches in diameter was used for applying heat to the fabrics. In order to hold the high temperatures desired, an 1,800-watt heating element was provided in the shoe. This element, of the flat ribbon type, was well embedded in a composition insulating material and when placed in position next to the metallic mass of the shoe was further insulated from the rear frame by layers of asbestos. A sheet of copper about 23 inches long was placed between the insulated heating element and the metal mass of the shoe to serve as an equalizer of temperature over the most used area of the shoe. By means of a variable resistance placed in the heating circuit, it was possible to compensate for changes in the line voltage as well as for cooling effects produced by the fabrics while being ironed.

The temperature of the heated shoe was determined from potentiometric readings of the electromotive force generated when the thermocouple junction with its leads was placed in the metal just below the ironing surface. Preliminary measurements had been made to determine the necessary depth of immersion of the thermoelement in the iron mass of the shoe.[18]

All thermocouples used in this work were made from no. 30 B. & S. gage chromel and constantan wires which had been enameled and then wound with asbestos. On account of the necessary forward and backward motion of the shoe in starting or stopping, it seemed advisable to use rather sturdy materials. As has been confirmed recently by Kratz and Broderick (*34*), the chromel-constantan combination also gave the advantage of a comparatively high electromotive force per degree of temperature change. Each thermocouple was calibrated by the United States Bureau of Standards, but no appreciable difference was found.

Preliminary thermocouple measurements taken for a distance of 15 inches along the central portion of the 26-inch shoe gave practically no variation over that distance. Accordingly, for the ironing of samples 15 inches wide, it was only necessary to make temperature observations in the middle portion of the surface in contact with the sample. There was then no danger of short circuits from thermocouples placed at various positions in the metal. The total ironing surface of the shoe amounted to approximately 140 square inches.

[18] Acknowledgment is made to W. P. White, of the Geophysical Laboratory, Carnegie Institution of Washington, for criticisms and suggestions in this connection.

The revolving roll of the ironer was well padded with two layers of 5/8-inch knit cotton padding and two layers of napped, double-faced cotton felt. Over this, covers of preshrunk muslin were used. These were changed often to avoid possible contamination of the experimental samples from any oxidized cellulose which might be formed on the covers with repeated use. The padding was fluffed up and aired often so as to prevent uneven packing on the roll.

Measurements upon the compressed springs at the back of the shoe indicated an average pressure between the padded roll and the heated shoe of 1¼ to 1½ pounds per square inch. This same pressure setting was maintained throughout the study.

Preparatory to ironing, sheeting samples 19 by 15 inches were conditioned at 65 percent relative humidity and 70° F. for 6 hours, a length of time sufficient according to the results described by Sommer (*49*). In order to estimate the moisture content, weighings were made of representative conditioned samples before and after drying to constant weight at 105° C. The values thus obtained for moisture content are: Good Middling, 6.22 to 6.25 percent; Middling, 6.18 to 6.32 percent; Strict Good Ordinary, 6.34 to 6.45 percent.

In order to keep the moisture content constant before ironing, each conditioned sample was wound on a moisture-proof roll between two similar pieces of conditioned cloth. The roll was then wrapped in moisture-proof material and placed in a covered container which had been standing open in the conditioning room. Weighings of samples which had been wrapped as described showed the moisture content to be practically unchanged even after the rolls had been removed from the conditioning room for 1 week. This finding confirms the experience of Guest and Potsdamer (*27*) in their work on fabric conditioning.

Each sample was run through the ironer once. The entire time required for any part of a given sample to pass the heated metallic shoe was about 2½ seconds.

The surface of the roll just before making contact with the heated metal was 38° to 40° C. for the major portion of the work. However, some observations were also recorded when the surface of the roll had a temperature range of 120° to 130°. In the course of household ironing, the roll surface sometimes rises to these temperatures, due to the turning of the roll against the heated shoe when no articles are being passed through the ironer. In order to estimate the approximate temperature of the roll surface, the thermo element, covered with a heat-retaining pad, was placed in position on a thin copper sheet which could be easily bent to make close contact with the roll. Checks made with this arrangement under known conditions showed it to be sufficiently accurate for this purpose.

MEASUREMENTS OF DETERIORATION

Measurements were made upon the ironed samples to detect changes in breaking strength, in surface color, and in the chemical nature of the cloth. The same tests were made on undamaged control samples of the same warp and the same filling taken from the immediate vicinity of the samples on which measurements were made. For the results recorded in this report, the values obtained from the control samples from any one grade of sheeting were averaged, and the test results expressed with reference to the average control value for the type of sheeting involved. The lowest ironing temperature tabulated is 145° C. since preliminary tests showed that the samples ironed at that temperature gave the same results as unironed samples.

BREAKING STRENGTH

Strips 6 inches long and 1 inch wide were used for the tensile-strength measurements, which were obtained under standard conditions of humidity and temperature with a Scott tester having a 3-inch back and front jaw and a distance between the top and bottom jaws of 3 inches. The rate of separation of the jaws was 12 inches per minute.

SURFACE REFLECTANCE

Tests for changes in color were made by means of a partial spectrophotometric method described by Appel (*4*). The intensity of light reflected by the samples was measured with reference to a standard magnesium oxide surface for the following range of wave lengths: 703, 651, 578, 546.1, 501, 435.8, and 405 millimicrons. The measurements of the light reflection in the violet range (mercury lines 435.8 and 405 millimicrons) were the most effective in detecting slight surface changes due to ironing, and it was possible to distinguish the damaged from the undamaged samples by observations for wave length 435.8 millimicrons.

The general arrangement of the apparatus and the position of the sample in its rotary holder is shown in figure 26.[19] The test sample and the standard white surface are mounted in interchangeable positions on the sliding platform. For an observation this is moved back so that the sample and standard are directly under the source of light. The 220-volt mercury arc lamp, as well as the 1,000-watt tungsten filament lamp, are mounted in the sliding carriage, which may be shifted to the right or left, according to the illumination desired for the sample. Readings are obtained with the Martens photometer, which is fixed in position so that the line of vision is perpendicular to the reflecting surface underneath. A more detailed description of this apparatus has been published by Appel (*4*).

FLUIDITY IN CUPRAMMONIUM SOLUTION

Fluidity (viscosity) tests were found to be a satisfactory means of measuring a tendered condition in ironed samples. These tests depend upon the fact that a cuprammonium hydroxide solution of the damaged cotton flows through a capillary tube more rapidly than does a similar solution of the undamaged cloth. The general method of observation followed that of Herschel and Bulkley (*28*), in which the time of flow for successive 5-cc portions is obtained. Figure 27 illustrates the particular arrangement of the fluidity tubes used in this laboratory. The constant temperature bath used accommodates 4 tubes, allowing 3 to come to the required temperature (25° C.) while measurements are being made on the fourth. The average

[19] Acknowledgment is made to the Textile Section of the Division of Fibrous and Organic Materials, U.S. Bureau of Standards, for the use of this equipment.

diameter of each capillary tube was obtained from flow tests with oils, the viscosities of which had been determined by the United States Bureau of Standards.

While the cuprammonium solution used for these fluidity measurements was of the same general type employed by Clibbens and

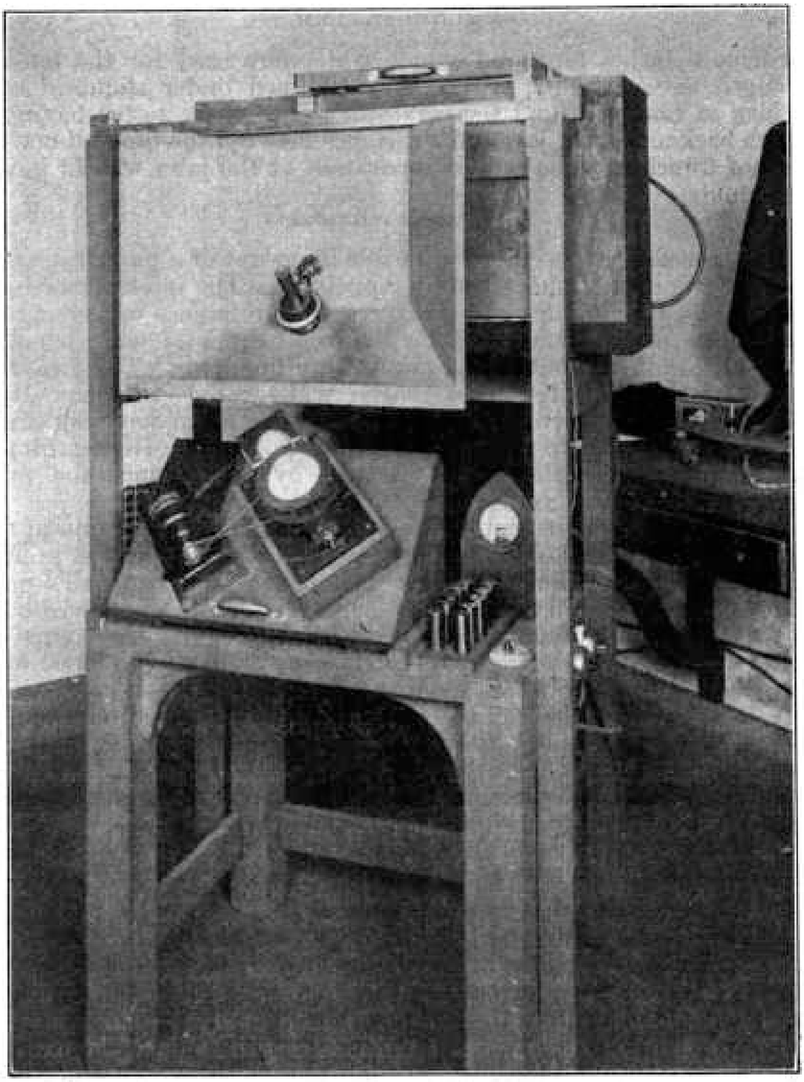

FIGURE 26.—Apparatus for the measurement of light reflectance.

Geake (*15*) modifications were made in its analysis (*11*, *12*). A solution containing 15 grams of copper, 200 grams of ammonia, and less than 0.5 gram of nitrite per liter was carefully prepared. As it was necessary during preparation to protect the solution from both heat and light, ice and a covering impervious to light were placed around the tube containing the electrolytically prepared copper and the concentrated ammonium hydroxide to which 10 grams of sucrose per liter had been added. Purified air was bubbled through this mixture until the desired concentration of copper was reached. After the final solution had been analyzed and diluted to the proper concentration of copper and ammonia, it was stored in an atmosphere of

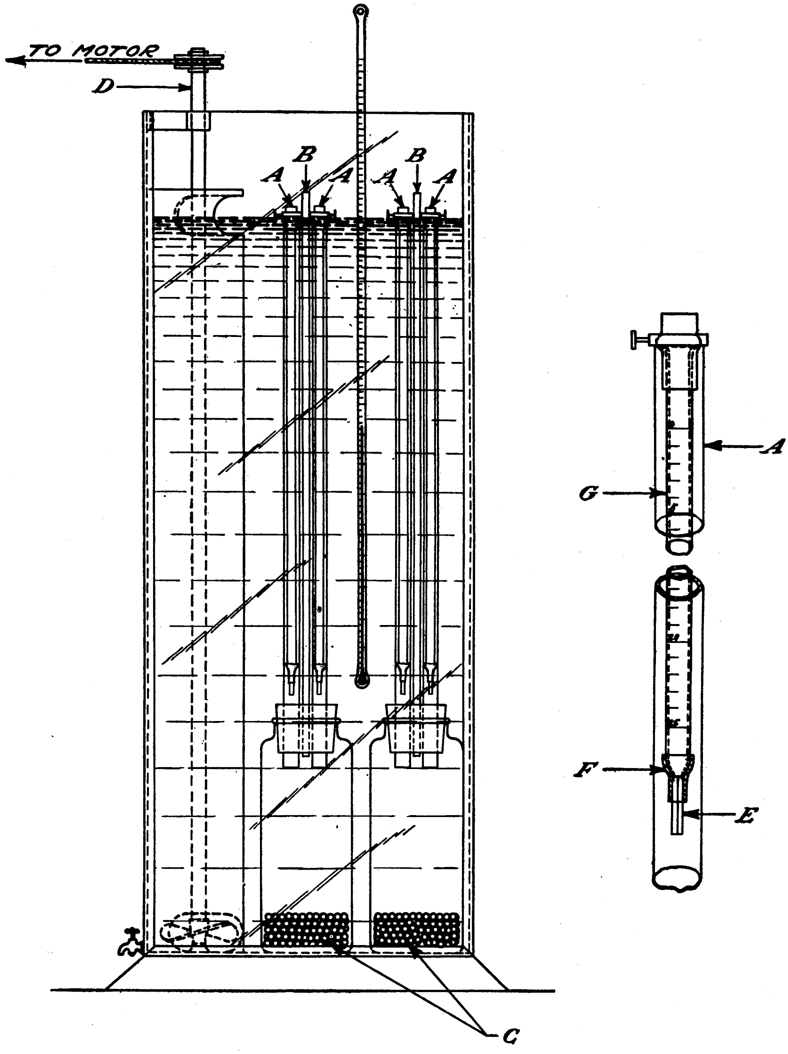

FIGURE 27.—Viscometer arrangement: *A*, Viscometer in glass jacket; *B*, air outlet tube; *C*, shot used for weight; *D*, axis leading to stirrer; *E*, capillary tube in position for observation; *F*, rubber connection; *G*, viscometer tube graduated in cubic centimeters.

nitrogen in a cool, dark place. As this solution decomposes under certain conditions within approximately 1 month, new solutions were made up from time to time.

The fabric test samples for the fluidity measurements were finely divided in a nonheating mill, which had a cutting action and was equipped with 1-millimeter openings through which the disintegrated fabric passed. Solution was also facilitated by the use of steel cylinder stirrers. Breakage of viscometers was avoided when the stirrers were fitted with spiral steel springs at each end as recommended by Neale and Stringfellow (*39*). After the finely divided cotton was thoroughly conditioned under standard procedure, sufficient amounts were weighed out to make 0.5-percent solutions of this cotton in the fluidity tubes. These tubes were then filled with cuprammonium, slipped into black cloth jackets and rotated overnight on a special viscosity wheel. This wheel, made of solid composition board, has four times the capacity of the bicycle wheel used by Clibbens and Geake (*15*). It is equipped on both sides with metal fasteners into which the tubes can be pressed easily. This eliminates the loss of time and the difficulty which would be involved in binding the tubes to the spokes of the bicycle wheel. When the cotton was finally dissolved in the cuprammonium, the solution was ready to be run through the capillaries of the fluidity tubes.

The fluidity results recorded in table 30 have been calculated from the formula $F=\frac{q}{C(P-p)}$, where F is the fluidity in reciprocal poises, C is an instrumental constant, q is the rate of flow in cubic centimeters per second, and the quantity, $(P\text{-}p)$, the average pressure causing flow (grams per square centimeter). Comparison of the cotton solutions with a true viscous liquid showed them to be for all practical purposes within the range for which the flow may be expressed in the form of fluidity as calculated by the above formula (*15*). The instrumental constant C is defined in centimeter-gram-second units by the quantity $\frac{\pi g d^4}{128L}$, where g is the acceleration of gravity, d is the inner diameter of the capillary tube, and L is the length. In the present work the values d and L were 0.1136 centimeters and 3.23 centimeters, respectively. Kinetic energy corrections were for the most part of no significance for measurements upon the materials used.

The ratio $\frac{q}{P-p}$ was obtained from flow-pressure graphs such as are shown in figure 28, where the ordinates represent the rate of flow, q, and the abscissae the corresponding value of the pressure head, P. The yield value, p, is given by the distance from the origin to the intersection of the straight line graph with the pressure axis. The method of Herschel and Bulkley (*28*) was used in determining the average pressure heads.

COPPER NUMBER

Determinations of copper number and of methylene blue absorption gave additional information both as to the extent and type of the degradation products formed in the ironing of the cotton materials. A method of determining the copper number of cotton and its use as a measure of the deterioration of this fiber has been discussed by Elmquist (*18*). In this study, a sample of the fabric weighing 1.5 grams was prepared in the same way outlined in that paper. However, in order to insure results that would be readily reproducible from day to day, the finely divided samples were treated with

Braidy's solution instead of Fehling's solution (*10*). Each of these samples, which had been placed in Erlenmeyer flasks fitted with Bunsen valve stoppers, was heated for 3 hours in an oil bath thermostatically controlled at 100° C. The copper number, as reported, is the number of grams of copper reduced from an alkaline solution of cupric sulphate by 100 grams of dry cotton.

TABLE 30.—*Physical and chemical changes caused by various ironing temperatures on desized sheetings made from the 3 selected cottons*

[Temperature of ironer roll, 38° to 40° C.]

Grade of cotton	Temperature of ironing surface	Fluidity	Copper number	Methylene blue absorption	Reflectance relative to magnesium oxide (wave length, 435.8)	Tensile strength [1]	
						Warp	Filling
	°C.	*Reciprocal poises*				*Pounds*	*Pounds*
Good Middling (No. 3)	145	13.38	0.426	1.77	0.842	61.0	42.0
	243	13.38	.426	1.77	.842	61.0	42.0
	246	13.38	.426	1.77	.832	61.0	42.0
	254	13.38	.426	1.77	.825	61.0	42.0
	257	13.41	.429	1.73	.820	61.0	42.0
	271	13.80	.469	--------	.804	61.0	42.0
	287	13.96	.480	1.57	.790	61.0	42.0
	303	--------	--------	--------	.776	61.0	42.0
	320	14.55	.491	1.51	.752	58.3	40.3
	335	15.11	.540	1.49	.725	53.3	37.4
Middling (No. 5)	145	13.96	.444	1.78	.828	57.8	37.3
	243	13.96	.444	1.78	.828	57.8	37.3
	245	13.96	.444	1.78	.813	57.8	37.3
	257	14.04	.451	1.73	.805	57.8	37.3
	271	14.29	--------	1.67	--------	57.8	37.3
	287	14.57	.516	1.62	.772	57.8	37.3
	303	--------	--------	--------	.762	57.8	37.3
	320	15.24	.552	--------	.739	54.6	35.6
	336	15.78	.580	1.52	.708	49.4	32.8
Strict Good Ordinary (No. 8)	145	14.89	.473	1.77	.812	50.0	32.2
	243	14.89	.473	1.77	.812	50.0	32.2
	246	14.89	.473	1.77	.803	50.0	32.2
	255	14.89	.473	1.77	--------	50.0	32.2
	257	14.91	.476	1.73	797	50.0	32.2
	271	15.24	.500	1.68	.782	50.0	32.2
	304	15.63	.523	1.60	.759	50.0	32.2
	320	16.14	.564	--------	.731	47.7	30.8
	334	16.36	.581	1.55	.707	44.8	29.4

[1] Strip method.

ABSORPTION OF METHYLENE BLUE

The methylene blue absorption was determined in a neutral solution of methylene blue buffered with potassium dihydrogen phosphate and sodium hydroxide. The ironed samples were cut as for the copper number and the fluidity measurements; otherwise the method followed was that of Clibbens and Geake (*14*). When the finely divided cotton had been thoroughly conditioned, 2.5-gram samples were added to 15-cc portions of the methylene blue solution in special tubes. Care was taken to insure thorough wetting. After standing 18 hours, the solution was separated by centrifuging and 10 cc of this titrated against napthol yellow S, one molecule of which couples with two molecules of methylene blue. The absorption of methylene blue in millimols per 100 grams of dry cotton is calculated from the difference of titer of 10 cc before and after immersion of the cotton.

DISCUSSION OF RESULTS

In the interpretation of results obtained in this study, no change was regarded as significant which was less than 1 percent of the value given by the undamaged material. All changes in the ironed fabrics were corroborated by repeated tests, and the representative results summarized. A general examination of the values shows that a deteriorated condition exists in the test samples at ironing temper-

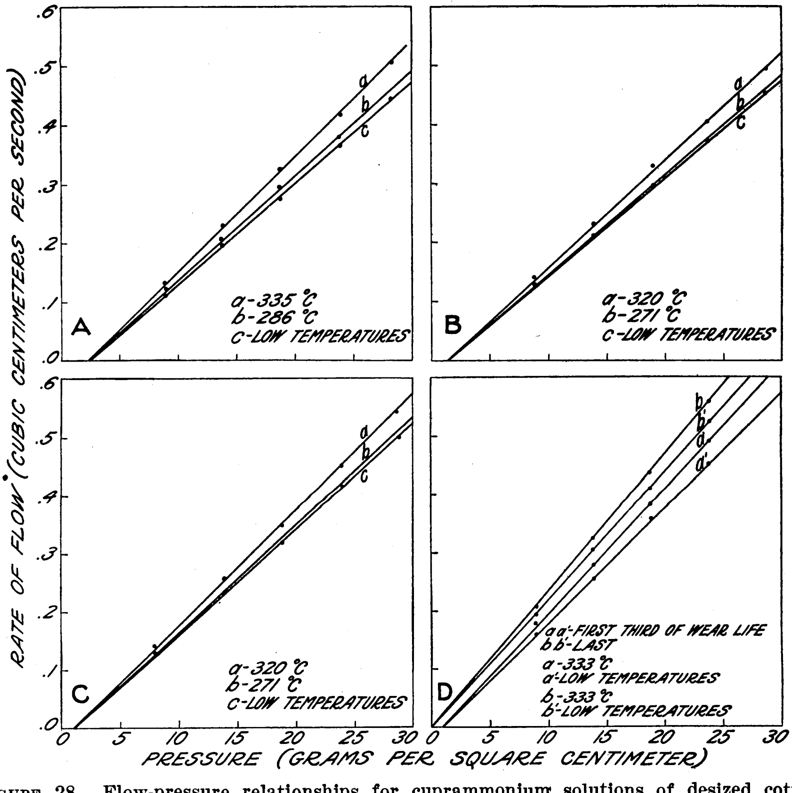

FIGURE 28.—Flow-pressure relationships for cuprammonium solutions of desized cotton sheetings ironed at various temperatures: *A*, Good Middling cotton; *B*, Middling cotton; *C*, Strict Good Ordinary cotton; *D*, used sheetings (Strict Good Ordinary cotton).

atures considerably lower than those at which a loss in breaking strength is first evident. There are no striking differences in the resistance to heat shown by the three sheetings under the experimental conditions of the present study. While there is some indication that high ironing temperatures have less effect on sheeting made from Strict Good Ordinary cotton, any conclusion in regard to this must be made with some reservation, particularly since this material after desizing was somewhat lower in weight and thickness than the other two sheetings.

NEW DESIZED SHEETINGS

Representative test results for the three desized sheetings ironed on the cooler roll surface are given in table 30. For the desized materials, before being ironed, there is an increase in breaking strength and surface reflectance as well as a decrease in copper number and fluidity in the following order: Strict Good Ordinary, Middling, Good Middling. The fluidity values and the copper numbers both give slight indication of deterioration in the desized materials ironed at 257° C., while at 271° changes of several percent are noticeable in the fluidity values and even larger relative changes in the copper numbers. After the first slight indications of damage the copper number appears to increase more rapidly than the fluidity for samples ironed at the same temperatures. The sensitiveness of the copper-number determinations to the deteriorated condition in the ironed materials seems to indicate that the modified cellulose here is entirely of the reducing type. This deduction is further strengthened by the values for the methylene blue absorption which decrease as the temperatures rise. At the higher temperatures the rate of this decrease becomes smaller and the absorption tends toward a limiting value. The same reducing type of oxidation product described here was obtained by Barr and Hadfield (*8*) when they exposed cotton fabrics to sunlight in the presence of air or oxygen. Changes of a similar nature due to mild oxidation with chlorine were also described by Birtwell, Clibbens, and Ridge (*9*).

There was no marked variation in the amount of tendering received by the different sheetings as shown by the flow-pressure diagrams of the cuprammonium solutions of cotton (fig. 28, A, B, C). These graphs also show that the yield value as represented by the intercept on the pressure axis apparently decreases with the lower grades of cotton. The line *c* in each individual group was obtained with a solution of the undamaged material. The faster flow of the solution of damaged material is shown graphically by the lines of greater slope. For both the Middling and the Strict Good Ordinary cotton, line *a* gives the flow-pressure relationship obtained with a solution of the material ironed at 320° C. The data in table 30 show that 320° is in the temperature range for which changes in breaking strength were first evident. Line *a* in the sheeting group of Good Middling cotton represents the flow-pressure relation for a solution of material ironed at 335°. At this temperature the loss in the breaking strength of the Good Middling cotton sheeting varied from 11 to 13 percent.

A review of the results shows that the modified cellulose obtained under the conditions of this study was always accompanied by a measurable loss in the surface reflectance of the fabrics for light of wave length 435.8 millimicrons. However, since there are so many factors which may be responsible for surface color change, other tests must be made to determine the nature and extent of degradation. Surface changes, as measured by the reflectance, appeared at ironing temperatures as low as 245° to 247° C.

The curves in figure 29 are representative of the reflectance results obtained when the desized materials are ironed with the cooler roll. Curve *a* in each group represents the results given by the undamaged material. A comparison of the lower curves with this one shows that the greatest relative change in light reflection occurs in the violet part of the spectrum (435.8 and 405 millimicrons).

Curves *d* and *e* in each group are the only ones showing a noticeable change in the red part of the spectrum (651 and 703 millimicrons). These are of special interest since they were obtained with samples ironed at temperatures high enough to produce measureable loss in tensile strength (320° and 334° to 336° C.). For the samples ironed at 303° to 304° no change in relative reflectance can be noted at 703 millimicrons, and there is only a very slight difference at 651 millimicrons.

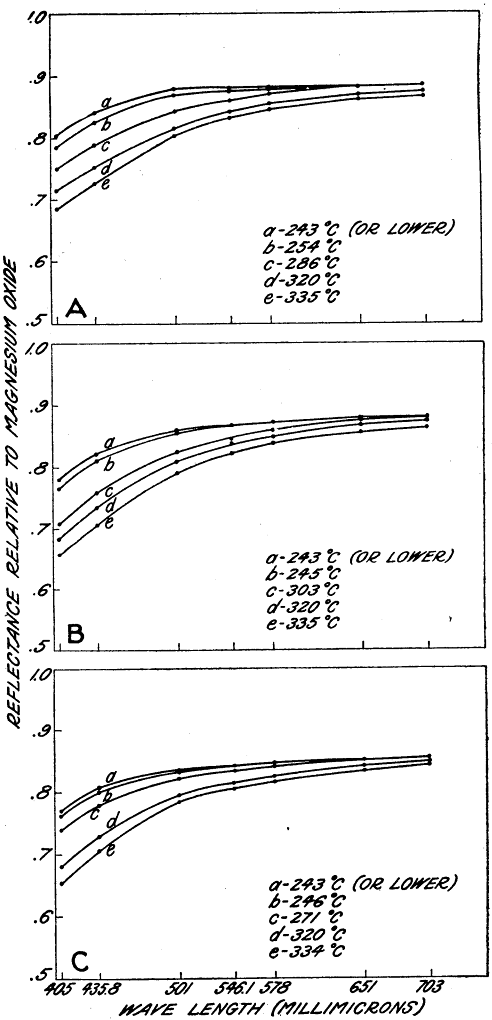

FIGURE 29.—Reflectance curves for new desized sheetings ironed at various temperatures: *A*, Good Middling cotton; *B*, Middling cotton; *C*, Strict Good Ordinary cotton.

The general experimental conditions represented in table 31 differ from those of table 30 only in the higher surface temperature of the roll (120° to 130° C.). As this is only an occasional condition in the average household ironing procedure, it seemed unnecessary to make extensive observations with the hotter roll. The results obtained with the three different sheetings gave no conclusions inconsistent with those already drawn from table 30. They suggest the same type of altered cellulose characterized by increased fluidity, higher copper numbers, and lower methylene blue absorption. The first indications of change in any of these three quantities occurred in the temperature range 224° to 226°, and in general, the changes noted appeared at temperatures fully 30° below those giving similar results with the cooler roll surface.

TABLE 31.—*Physical and chemical changes caused by various ironing temperatures on desized sheetings made from the 3 selected cottons*

[Temperature of ironer roll, 120° to 130° C.]

Grade of cotton	Temperature of ironing surface	Fluidity	Copper number	Methylene blue absorption	Reflectance relative to magnesium oxide (wave length, 435.8)
	°C.	*Reciprocal poises*			
Good Middling (No. 3)	145	13.38	0.426	1.77	0.842
	218	13.38	.426	1.77	.842
	220	13.38	.426	1.77	.829
	226	13.50			.821
	232	13.59	.453		.804
	244			1.66	.796
	259	14.31	.485	1.60	.785
Middling (No. 5)	145	13.96	.444	1.78	.828
	218	13.96	.444	1.78	.828
	219	13.96	.444	1.78	.818
	224	13.96	.444	1.76	.810
	232	14.47	.465	1.70	.790
Strict Good Ordinary (No. 8)	145	14.89	.473	1.77	.812
	217	14.89	.473	1.77	.812
	220	14.89	.473	1.77	.803
	224	14.89		1.76	.797
	232	15.12	.493	1.72	
	239			1.69	
	258	15.56	.511		.773
	285	16.04			.747

Measurements of the violet light (wave length, 435.8 millimicrons) reflected from the surface of the ironed samples indicated a decreased reflectance at 220° C. With the cooler roll the same relative changes occurred in the range 245° to 247°.

Tests for breaking strength on sheeting of Strict Good Ordinary cotton gave approximately a 9 to 10 percent loss at 292° C. and between 3 and 5 percent at 285° C. These are at least 30° lower than the temperatures giving the same changes with the cooler roll. Similar results were obtained with the other two cottons.

USED SHEETINGS

The diagrams in figure 28, D, give the flow-pressure relationship for solutions of used cotton sheetings ironed on the cooler roll surface. The two lower lines, *a*, *a′*, were obtained for sheeting ironed at the end of the first third of its wear life at temperatures 333° and 145° C., respectively. The lines, *b*, *b′*, represent flow-pressure relations for sheeting in the last third of its period of use. It is evident that a solution of the more used material shows a smaller relative change in its flow than does the less worn material under the same range of ironing temperatures. While the results illustrated here were obtained with sheetings of Strict Good Ordinary cotton, the same changes were obtained with the Good Middling and the Middling during the last half of their wear life. A comparison of C and D in figure 28 shows that the new desized sheeting has approximately the same yield value as the used material at the end of the first third of its wear life, but during the last half of the period of use the yield value shifts to zero. This was also the finding with the two sheetings woven from Good Middling and Middling cotton.

The numerical values of the fluidity given by some of the more worn material for the low and high ironing temperatures (145° and 333° C.) were 20.2 and 21.3, respectively. For the same temperature range the copper numbers of this material were 0.892 and 0.996, indicating no unusually large change. Contrary to the usual decrease in methylene blue absorption obtained with the newer materials, there was an increase for the more worn sheetings. However, at the end of the first third of its useful life, this material gave only slight increases in absorption, and in the first one tenth of its wear life there was a decided decrease under the same ironing conditions. If additional results confirm this change to an increase in methylene blue absorption for worn materials generally under the influence of heat, it is possible that absorption measurements on materials heated under controlled conditions could be used in developing a method to distinguish used cotton from new. The need for such a test has been stressed by Winne and Donovan (*56*) in the examination of filling materials used in bedding and upholstered furniture.

The reflectance curves given by the used cotton sheetings ironed with the cold roll at 145° and 333° C. are shown in figure 30. The sheeting at the end of one third of its wear life gives about the same relative decrease in surface reflection at 435.8 millimicrons as is given by new sheeting with approximately the same ironing temperature. However, after two thirds of its useful life this material shows a much greater relative decrease in reflectance. The same relatively large surface change existed at 330° to 334° for all samples measured during the last third of the period of use regardless of the fact that the weights decreased from 3.7 to 3.3 ounces per square yard. This same type of surface change was found with all three sheetings, but the results given here were obtained with the sheeting woven from Strict Good Ordinary cotton.

In view of the increased darkening of the most worn materials at high ironing temperatures, determinations were made of the fat content as well as the pH extract of the unironed materials. Even for the sheeting in the last period of its wear life the fat content was not found to be essentially different from that of the new desized materials. The pH of the extract obtained from 5-gram samples of both the worn and the new materials immersed in 100 cc of boiling water for 1 hour according to a method described by New (*40*) was approximately the same as that of the distilled water used. All the worn sheeting materials used in these experiments were thoroughly rinsed in distilled water before being ironed. It is of course possible that the darkening of the fabrics in their more worn state may be somewhat analogous to the condition described by Fort (*20*) in connection with the heat test applied to tendered cotton. His method, however, was developed as a means of detecting oxidation tendering, which may not be particularly great for materials under normal conditions of use. The yellowing effect upon oxidation products of the reducing type has also been recorded by Birtwell, Clibbens, and Ridge (9).

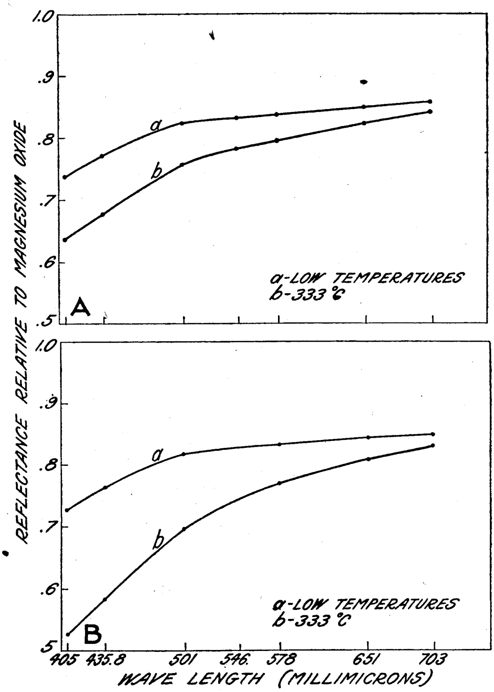

FIGURE 30.—Reflectance curves for used sheetings made of Strict Good Ordinary cotton: *A*, First third of wear life; *B*, last third of wear life.

CONCLUSIONS

Three sheetings made from selected cottons representative of the Good Middling (No. 3), Middling (No. 5), and Strict Good Ordinary (No. 8) grades, respectively, were ironed at known temperatures with a household ironer of the roll type with a pressure between 1¼ and 1½ pounds to the square inch. Each fabric sample was conditioned at 65 percent relative humidity and brought in sliding contact with the heated metallic shoe for about 2½ seconds.

The desized materials damaged by ironing were characterized by increased fluidity in cuprammonium solution, higher copper numbers, and comparatively low methylene blue absorption as well as by a decreased surface reflectance in the violet part of the spectrum.

Similar changes were obtained in the three types of sheeting under the ironing conditions described. The Strict Good Ordinary showed a slightly greater resistance to heat than the other two, but the sheeting of this cotton was found to be somewhat lower in weight and thickness after desizing than were the others.

At ironing temperatures above 245° C. changes were observed in all the sheetings when the initial surface temperature of the padded roll was 38° to 40°. The first appreciable loss in tensile strength appeared in the range 315° to 320°. Slight indications of chemical deterioration were obtained as low as 256° to 257° and changes in surface reflectance first occurred at 245° to 247°.

When the roll surface attained a temperature from 120° to 130° C., indications of deterioration were obtained for ironing temperatures 25° to 30° lower than with the cooler roll. At 220° a decreased surface reflectance was noted for light in the violet part of the spectrum, and the first indications of chemical degradation occurred from 224° to 226°.

In the first third of its useful life the worn sheeting of all three types scorched no more easily than the new desized material. However, in the last third of its wear life the worn material was much more easily darkened, as shown by a decreased surface reflectance at the higher temperatures. It also had a higher methylene blue absorption.

An ironing procedure was developed in this study which involved the control, maintenance, and measurement of the temperature of the ironer, the control of the moisture content of the fabric to be ironed, and the regulation of time and pressure factors. The methods described are applicable to research on ironing and on temperature effects in finishing during manufacture.

SUMMARY

In an effort to compare some properties of cotton fibers, yarns, and fabrics, and to furnish a basis for studying the relation of the quality of raw cotton to the service, laundering, and ironing properties of fabrics manufactured from them, 3 bales of American upland cotton from the Texas area, crop 1928–29, selected to represent each Good Middling, Middling, and Strict Good Ordinary grades, approximately 1 inch in staple length, and similar in character, were manufactured into sheeting of a definite construction and subjected to service and ironing tests. The described conditions and procedures employed were controlled and were comparable, insofar as possible.

Observations were made on the behavior of the cottons during manufacture and some precise measurements were obtained on the fibers in the raw stocks and on their intermediate products, yarns, and fabrics; certain physical and chemical analyses were made on the sheets as a basis of determining their serviceability and their resistance to ironing conditions. The setting of the problem, the materials and procedure employed, the results obtained, and the specific conclusions drawn are presented in the distinct but closely related parts of the bulletin.

In considering the findings here reported, it should be pointed out that the observations made are generally in line with those previously made in experimental and commercial manufacture of cottons of different grades. In certain instances, the three cottons have not given results which would be anticipated from their grade designations. However, the grade factors do not refer to fiber properties which in the final analysis must largely control the spinning behavior and the yarn and fabric characteristics. Within any given grade, for instance, these fiber properties may vary greatly and it is this variability which mills seek to overcome by mixing the stock

from a considerable number of bales. Samples in the form of individual bales taken from certain grade categories, therefore, can give only a limited picture of the average and range of spinning quality associated with grade. It is believed, nevertheless, that the present results are well worth while for indicating something of the range of results to be obtained from the different grades and for orienting the attack in future studies.

The Good Middling and Strict Good Ordinary cottons furnished waste in quantity considered average for their respective grades; the Middling cotton gave somewhat less waste than the average of this grade. During the course of manufacture, the length of fibers from the three cottons did not change appreciably. The number of ends broken per 100 spindles per hour increased with decreasing grade. As a result of the finishing process, a reduction of about 14 percent occurred in the width of the sheeting, accompanied by about a 3-percent increase in length.

The brilliance of the raw cottons decreased as the grade became lower and, although the spread became smaller after bleaching, this relation was evident for the cottons throughout their manufacture. In general, the spectrophotometric measurements made on the fabrics established a similar relation, but some differences in reflection were observed between the gray and the bleached fabrics, as explained. Although the gray fabrics manufactured from the lower grades showed on the average a larger number of fine particles of foreign matter, the finished fabrics were practically free of such extraneous matter.

The yarns made from the Good Middling and Middling cottons were approximately equal in strength; those from the Strict Good Ordinary were 10 to 18 percent weaker than those from either of the other two grades. The corrected tensile strength of the gray and of the bleached fabrics decreased as the grade became lower, but the relative strength of the fabric from the Middling cotton was much nearer to that for the Good Middling than to that for the Strict Good Ordinary. The bursting strength of the gray and of the bleached fabrics from the Good Middling and Middling cottons was about equal and was much higher than that of the corresponding fabrics made from the Strict Good Ordinary. Bleaching resulted in a reduction of approximately 33 percent in bursting strength for the fabrics.

The changes in the physical and chemical characteristics of the sheetings that were made from these three selected cottons and subjected to controlled service and laundering were determined at intervals during their wear-life. Tests were made for weight, thread count, thickness, breaking strength, bursting strength, shrinkage, fluidity in cuprammonium solution, copper number, and methylene blue absorption.

As measured by physical tests the sheets of Strict Good Ordinary cotton were weaker initially and throughout their period of wear than those made of Middling and Good Middling cotton. The latter two were of the same order. The sheets woven of Strict Good Ordinary were slightly more deteriorated at the end of 200 washes than were the others at the end of 225. The copper number and methylene blue absorption tests in this study showed that the cellulose of the Strict Good Ordinary cotton was less degraded during the major part of its wear life than was that of the other two cottons. However, in the last stages of wear it was slightly more deteriorated. The oxidation product formed was characterized by greatly increased affinity for methylene blue.

The maximum wear occurred on all of the sheets at the section usually occupied by the shoulders. There was no increased wear on the middle fold and no change in the unused sheets after 3½ years' storage.

The new sheetings made of the selected cottons were desized and ironed under controlled conditions of temperature, time, pressure, and moisture. The ironing procedure was developed with a household ironer of the roll type in which the pressure maintained between the roll and the heated shoe was 1¼ to 1½ pounds per square inch. The time of sliding contact of the sample with the shoe was about 2½ seconds.

When the initial surface temperature of the padded roll was 38° to 40° C., no changes were produced in the cottons at ironing temperatures below 245°. At the highest ironing temperatures used all desized sheetings showed a lower breaking strength, a decreased surface reflectance in the violet part of the spectrum, increased fluidity in cuprammonium solution, higher copper numbers, and a comparatively low methylene blue absorption.

There was some indication of a slightly greater heat resistance for the desized sheeting made from Strict Good Ordinary cotton than for the other two sheetings. Before being damaged by ironing this desized material made from Strict Good Ordinary cotton had lower values for breaking strength and surface reflectance as well as higher values for copper number and fluidity than the sheetings from Middling and Good Middling cotton.

Worn sheetings made of the three selected cottons were subjected to the same ironing conditions after different periods of service. During the first third of their useful life they all showed physical and chemical changes similar to those obtained with the new desized materials. However, in the last third of their wear life, the worn materials showed a greater decrease in surface reflectance and a higher methylene blue absorption.

LITERATURE CITED

(1) ANONYMOUS.
1925. WHAT LAUNDRY TESTS SHOW ABOUT SHEETINGS. Mod. Hosp. 24: 390.

(2) AKAHIRA, T.
1928. RELATIONS BETWEEN CARBON, HYDROGEN, AND OXYGEN CONTENTS IN COTTON CELLULOSE UNDER THERMAL DECOMPOSITION, AND ITS WEIGHT LOSS. [Tokyo] Inst. Phys. and Chem. Research, Sci. Papers 9: [165]–180, illus.

(3) AMERICAN SOCIETY FOR TESTING MATERIALS.
1930. SPECIFICATIONS AND METHODS OF TEST FOR TEXTILE MATERIALS. PREPARED BY COMMITTEE D-13 ON TEXTILE MATERIALS. 122 pp., illus.

(4) APPEL, W. D.
1928. A METHOD FOR MEASURING THE COLOR OF TEXTILES. Amer. Dyestuff Rptr. 17: 49–54, illus.

(5) ASSOCIATES FOR GOVT. SERVICE.
1929. SERVICE TESTS OF BEDSHEETS. 7 pp. (The Cotton Textile Institute, Inc.) New York.

(6) BAIN, J. W.
1927. THE BEHAVIOUR OF CELLULOSE ON HEATING. Jour. Soc. Chem. Indus. 46: 193T–195T.
(7) BARR, G., and HADFIELD, I. H.
1927. THE NATURE OF THE ACTION OF SUNLIGHT ON COTTON. Jour. Textile Inst. 18: T490–T493.
(8) ——— and HADFIELD, I. H.
1930. THE ACTION OF SUNLIGHT ON COTTON IN THE PRESENCE AND ABSENCE OF OXYGEN. [Gt. Brit.] Dept. Sci. and Indus. Research, Fabrics Co-ordinating Research Com., Rpt. 2: 95–112, illus.
(9) BIRTWELL, C., CLIBBENS, D. A., and RIDGE, B. P.
1925. THE CHEMICAL ANALYSIS OF COTTON-OXYCELLULOSE, PART I. Jour. Textile Inst. 16: T13–T52, illus.
(10) BURTON, J. O., and RASCH, R. H.
1931. THE DETERMINATION OF THE ALPHA-CELLULOSE CONTENT AND COPPER NUMBER OF PAPER. Bur. Standards Jour. Research 6: 603–619, illus.
(11) BUTTERWORTH, E., and ELKIN, H. A.
1929. NOTE ON THE DETERMINATION OF COPPER AND NITRITE IN SOLUTIONS OF CUPRAMMONIUM HYDROXIDE. Jour. Soc. Chem. Indus. 48: 127T–128T.
(12) CARVER, E. K., BINGHAM, E. C., BRADSHAW, H., and VENABLE, C. S.
1929. A STANDARD METHOD FOR DETERMINING THE VISCOSITY OF CELLULOSE IN CUPRAMMONIUM HYDROXIDE. Indus. and Engin. Chem., Analyt Ed. 1 (1): 49–51, illus.
(13) CLAYTON, H. D.
1920. THE EFFECT OF HEAT UPON CLOTH. Laundryowners Natl. Assoc. Yearbook 1920: 222–231. [Original not seen.]
(14) CLIBBENS, D. A., and GEAKE, A.
1926. THE CHEMICAL ANALYSIS OF COTTON, XI.—THE ABSORPTION OF METHYLENE BLUE FROM BUFFERED SOLUTIONS. Jour. Textile Inst. 17: T127–T144, illus.
(15) ——— and GEAKE, A.
1928. THE MEASUREMENT OF THE FLUIDITY OF COTTON IN CUPRAMMONIUM SOLUTION. Jour. Textile Inst. 19: T77–T92, illus.
(16) ——— and RIDGE, B. P.
1928. THE TENSILE STRENGTH AND FLUIDITY OF CHEMICALLY MODIFIED COTTON. Jour. Textile Inst. 19: T389–T404, illus.
(17) CLIFFORD, P. H., HIGGINBOTHAM, L., and FARGHER, R. G.
1924. THE CHEMICAL ANALYSIS OF COTTON. THE DETERMINATION OF FAT, WAX, AND RESIN. Jour. Textile Inst. 15: T120–T137, illus.
(18) ELMQUIST, R.
1931. A MODIFIED METHOD FOR DETERMINING THE TENDERING OF COTTON. Jour. Home Econ. 23: 62–66.
(19) FORT, M.
1916. THE EFFECT OF CERTAIN AGENCIES UPON THE COLOUR AND DYEING PROPERTIES OF WOOL AND SILK. Jour. Soc. Dyers and Colourists 32: 184–187.
(20) ———
1932. A HEAT TEST APPLIED TO TENDERED COTTON AND LINEN FABRICS. Jour. Soc. Dyers and Colourists 48: 94–96.
(21) FURRY, M. S.
1929. SOME SPECIFICATIONS OF WIDE COTTON SHEETINGS BOUGHT ON THE RETAIL COUNTER. Textile World 76: 1169, 1171.
(22) ——— and EDGAR, R.
1928. AN ANALYSIS OF WIDE COTTON SHEETINGS. Jour. Home Econ. 20: 429–442.
(23) GILMORE, B. H.
1928. SCORCHING TEMPERATURES OF TEXTILES. A STUDY OF THE FACTORS OF INTENSITY AND TIME. Bull. Laundryowners Natl. Assoc. U.S. and Canada and Amer. Inst. Laundering 11 (10): 20–22, 24.
(24) GINTER, A. E., and RHODES, D.
1931. THE DURABILITY OF WHITE AND COLORED COTTON MATERIALS. Mo. Agr. Expt. Sta. Bull. 300: 83.

(25) GRIFFITH, M., and EDGAR, R.
1928. DETERIORATION OF FIVE WIDE COTTON SHEETINGS DUE TO LAUNDERING. Jour. Home Econ. 20: 111–120, illus.
(26) ——— SPRAGUE, T., BERG, V., and EDGAR, R.
1929. THE INFLUENCE OF LAUNDERING ON SOME COTTON AND LINEN FABRICS. Iowa State Col. Jour. Sci. 3: 215–225, illus.
(27) GUEST, I. S., and POTSDAMER, L. S.
1931. FABRIC CONDITIONING. Melliand Textile Mo. 2: 1448–1450.
(28) HERSCHEL, W. H., and BULKLEY, R.
1927. CALIBRATION OF THE BURET CONSISTOMETER. Indus. and Engin. Chem. 19: 134–139, illus.
(29) JOHNSON, G. H.
1930. HIGH TEMPERATURES AND TEXTILES. Bull. Laundryowners Natl. Assoc. U.S. and Canada and Amer. Inst. Laundering 13 (5): 8–10, illus.
(30) JUSTIN-MUELLER, E.
1921. ACTION COMPARATIVE DE LA CHALEUR SUR LA CELLULOSE, L'HYDRO ET L'OXYCELLULOSE ET CARACTÉRISATION DE L'HYDROCELLULOSE PAR LA CHALEUR SÈCHE. Bull. Soc. Chim. France (4) 29: 987–988.
(31) KEUFFEL, C. W.
1925. A DIRECT READING SPECTROPHOTOMETER. Jour. Opt. Soc. Amer. and Rev. Sci. Instruments 11: 403–410, illus.
(32) KNECHT, E.
1920. ON THE PROLONGED ACTION OF A MODERATE HEAT ON BLEACHED COTTON AND SOME OTHER SUBSTANCES. (PRELIMINARY NOTICE.) Jour. Soc. Dyers and Colourists 36: 195–198.
(33) ——— and MULLER, E. F.
1925. SOME FURTHER NOTES ON THE ACTION OF HEAT ON COTTON CELLULOSE. Jour. Soc. Dyers and Colourists 41: [43]–47.
(34) KRATZ, A. P., and BRODERICK, E. L.
1932. STUDY OF THE APPLICATION OF THERMOCOUPLES TO THE MEASUREMENT OF WALL SURFACE TEMPERATURES. Heating, Piping and Air Conditioning 4: 635–638, illus.
(35) MCCLEW, J.
1931. FIRST AID IN COTTON SHEET SHRINKAGE. RECENT EXPERIMENTS CONDUCTED AT THE UNIVERSITY OF WASHINGTON BRING TO LIGHT SOME INTERESTING FACTS AND SUGGEST A REMEDY FOR THIS PROBLEM. Natl. Laundry Jour. 102 (5): 30–31, illus.
(36) MACDONALD, E. S.
1929. SHEETING DURABILITY TESTS. Bull. Laundryowners Natl. Assoc. U.S. and Canada and Amer. Inst. Laundering 12 (7): 7–8, illus.
(37) MÖLLERING, O. H.
1928. ÜBER DIE EINFLUSSE HÖHERER DAUERERWÄRMUNGEN AUF TEXTILE ISOLIERSTOFFE. Leipziger Monatschr. Textil-Indus. 43: 249–251.
(38) MUNSELL COLOR COMPANY, INC.
1929. MUNSELL BOOK OF COLOR, DEFINING, EXPLAINING, AND ILLUSTRATING THE FUNDAMENTAL CHARACTERISTICS OF COLOR; A REVISION AND EXTENSION OF "THE ATLAS OF THE MUNSELL COLOR SYSTEM" . . . 42 pp., illus., Baltimore.
(39) NEALE, S. M., and STRINGFELLOW, W. A.
1932. THE SHRINKAGE OF COTTON YARN AND THE VISCOSITY OF ITS SOLUTIONS IN AQUEOUS CAUSTIC SODA-CUPRAMMONIUM HYDROXIDE. Jour. Textile Inst. 23: T177–T182, illus.
(40) NEW, A. A.
1932. DETERMINATION OF SMALL AMOUNTS OF ACIDS, ALKALIES, AND SALTS IN TEXTILES. Textile Manfr. 58 (686): 67, 68–69.
(41) NICKERSON, D.
1929. A METHOD FOR DETERMINING THE COLOR OF AGRICULTURAL PRODUCTS. U.S. Dept. Agr. Tech. Bull. 154, 32 pp., illus.
(42) ———
1931. A COLORIMETER FOR USE WITH DISC MIXTURE. Jour. Optical Soc. Amer 21: 640–642, illus.
(43) ———
1931. COLOR MEASUREMENTS IN PSYCHOLOGICAL TERMS. Jour. Optical Soc. Amer. 21: 643–650, illus.

(44) O'BRIEN, R., and STEELE, J.
1929. WHERE SHEETS WEAR OUT. BREAKAGE ON MIDDLE FOLD EVEN WHEN NOT PRESSED—SHOULDER WEAR. Textile World 75: 2393, 2427, illus.

(45) PALMER, A. W.
1924. THE COMMERCIAL CLASSIFICATION OF AMERICAN COTTON, WITH REFERENCE TO THE STANDARDS FOR GRADE, COLOR, AND STAPLE. U.S. Dept. Agr. Circ. 278, 35 pp., illus.

(46) PATEL, C. K.
1928. THE INFLUENCE OF HEAT ON THE AFFINITY OF COTTON FOR DYESTUFFS. Jour. Soc. Dyers and Colourists 44: 301–303.

(47) RAMSBOTTOM, J. E. and SNOAD, A. W.
1930. THE FIREPROOFING OF FABRICS. [Gt. Brit.] Dept. Sci. and Indus. Research, Fabrics Coordinating Research Comm. Rpt. 2: 16–94, illus.

(48) SCHÜLER, L.
1916. DIE WARMEBESTÄNDIGKEIT VON BAUMWOLLE UND PAPIER. Elektrotech. Ztschr. 37: 535–537, illus.

(49) SOMMER, H.
1930. THE INFLUENCE OF ATMOSPHERIC HUMIDITY UPON THE MOISTURE CONTENT OF TEXTILE FABRICS. Melliand Textile Mo. 2: 916–919, illus.

(50) TILTMAN, A. H., and PORRITT, B. D.
1928. THE EFFECT OF HEAT ON COTTON. INITIAL CHANGES IN TENSILE STRENGTH OF UNPROOFED COTTON. India Rubber Jour. 76: 245–248, illus.

(51) UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS.
1929. PROCEEDINGS OF INTERNATIONAL UNIVERSAL COTTON STANDARDS CONFERENCE OF 1929 AND ITEMS RELATING TO THE ADMINISTRATION OF THE UNITED STATES COTTON FUTURES AND COTTON STANDARDS ACTS. U.S.Dept.Agr., Bur. Agr. Econ., Serv. and Regulat. Announc. 117, 23 pp.

(52) ———
1931. REGULATIONS OF THE SECRETARY OF AGRICULTURE UNDER THE UNITED STATES COTTON STANDARDS ACT. U.S.Dept.Agr., Bur. Agr. Econ., Serv. and Regulat. Announc. 125, 23 pp.

(53) UNITED STATES DEPARTMENT OF COMMERCE, BUREAU OF STANDARDS.
1929. UNITED STATES GOVERNMENT GENERAL SPECIFICATIONS FOR TEXTILE MATERIALS. (METHODS OF PHYSICAL AND CHEMICAL TESTS). U.S. Dept. Com., Bur. Standards Circ. 293, 6 pp. (U.S. Gov't Master Specification no. 345a).

(54) WEBB, R. W.
1932. THE SUTER-WEBB COTTON FIBER DUPLEX SORTER AND THE RESULTING METHOD OF LENGTH-VARIABILITY MEASUREMENTS. Amer. Soc. for Testing Materials Proc. 32 (pt. 2): 764–771, illus.

(55) WILLIS, H. H.
1927. MANUFACTURING TESTS OF COTTON OF THE WHITE GRADES OF THE UNIVERSAL STANDARDS FOR COTTON. U.S. Dept. Agr. Bull. 1488, 30 pp., illus.

(56) WINNE, A. W., and DONOVAN, J. D.
1932. A METHOD DISTINGUISHING BETWEEN OLD AND NEW COTTON FIBERS. Melliand Textile Mo. 4: 298–299.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Assistant Secretary	REXFORD G. TUGWELL.
Director of Scientific Work	A. F. WOODS.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	SETH THOMAS.
Agricultural Adjustment Administration	CHESTER C. DAVIS, *Administrator.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	JAY N. DARLING, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	KNOWLES A. RYERSON, *Chief.*
Bureau of Plant Quarantine	A. S. HOYT, *Acting Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

This bulletin is a joint contribution from

Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Division of Cotton Marketing	ARTHUR W. PALMER, *Principal Marketing Specialist, in Charge.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Textiles and Clothing Division	RUTH O'BRIEN, *Senior Textile Chemist, in Charge.*

U.S. GOVERNMENT PRINTING OFFICE: 1934